DTIC/TR-97-1

AD-A319 216

The DTIC Review

Surviving Chemical and Biological Warfare

Vol. 2, No. 4
December 1996

The DTIC Review is published quarterly by the Defense Technical Information Center (DTIC), DTIC-BRR, 8725 John J. Kingman Road, Suite 0944, Ft. Belvoir, VA 22060-6218
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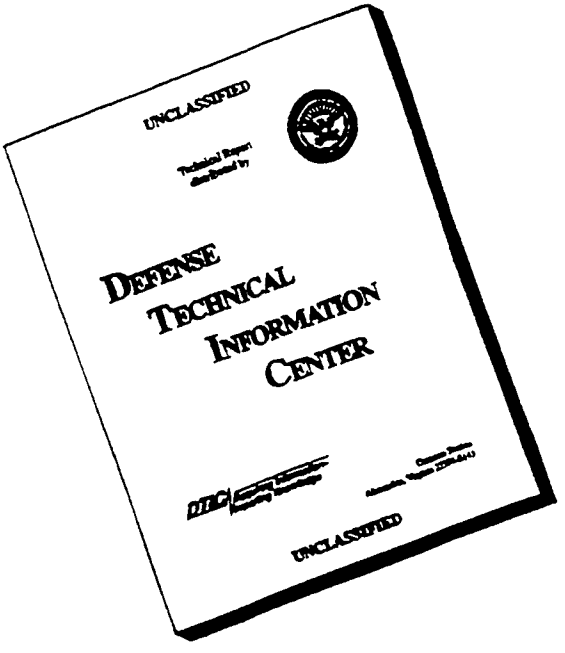

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
December, 1996

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
The DTIC Review
Surviving Chemical and Biological Warfare
Vol 2 No 4

5. FUNDING NUMBERS

6. AUTHOR(S)
Christian M. Cupp, Editor
Phyllis Levine ,Compiler

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Defense Technical Information Center
DTIC-BRR
8725 John J. Kingman Rd., Suite 0944
Ft. Belvoir, VA 22060-6218

8. PERFORMING ORGANIZATION REPORT NUMBER
DTIC/TR-97-1

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Same as #7

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
This publication is published irregularly by the Defense Technical Information Center

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution is unlimited

12b. DISTRIBUTION CODE
Statement A

13. ABSTRACT *(Maximum 200 words)*

Faced with a new era of warfare DoD is engaged in both active and passive defense strategies to respond, defend and survive in a chemical or biological environment. Potential threats require effective protection against attack. DoD training centers emphasize and include chemical and biological training in a realistic manner along with instruction in specific equipment and technology.

The authors of the following papers inform readers of the plans and tactics taken to protect the United States Armed Forces and civilian populations against chemical and biological warfare.

19970108 100

14. SUBJECT TERMS
Chemical Warfare, Chemical Weapons, Biological Weapons, Biological Warfare, Chemical Agents, Toxic Agents, Anthrax

15. NUMBER OF PAGES
216

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U2	U2	U2	unlimited

The DTIC Review

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AD-A319 216

DTIC

Vol. 2, No. 4
December 1996

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FOREWORD

Recent world events have heightened awareness of the potential threat posed by chemical and biological weapons to our armed forces and to civilian populations of allies. Surviving Chemical and Biological Warfare was selected as an important and timely topic for this issue of *The DTIC Review*. *The DTIC Review* brings its readers the full text of selected technical reports as well as a bibliography of other references of interest under one cover. This format provides our readership with a sampling of documents from our collection on particular topic of current interest. The editorial staff hopes that you find this effort of value and appreciates your comments.

Kurt N. Molholm
Administrator

INTRODUCTION

This collection of selected documents from the Defense Technical Information Center (DTIC) addresses the threat posed by chemical and biological warfare and the DoD response. Faced with a new era of warfare, DoD is engaged in both active and passive defense strategies to respond, defend and survive in a chemical or biological environment.

Potential threats require effective protection against attack. DoD training centers emphasize and include chemical and biological training in a realistic manner along with instruction in specific equipment and technology.

The authors of the following papers inform readers of the plans and tactics taken to protect the United States Armed Forces and civilian populations against chemical and biological warfare.

The selected documents and bibliography are a representation of the information available on chemical and biological warfare from DTIC's extensive collection on the subject. In-depth literature searches may be requested by contacting the Reference and Retrieval Branch at DTIC on (703) 767-8274, DSN: 427-8274, FAX: (703) 767-9070 or Email: bibs@dtic.mil.

DOCUMENT 1

American Military Readiness for Chemical and Biological Warfare: A Critical Vulnerability

AD-A311 911

June 1996

Naval War College
Newport, RI

NAVAL WAR COLLEGE
Newport, R.I.

AMERICAN MILITARY READINESS FOR CHEMICAL AND BIOLOGICAL WARFARE: A CRITICAL VULNERABILITY

by

Michael D. McCarten

Commander, Medical Corps, U.S. Navy

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: M D McCarten

14 June 1996

Paper directed by
Captain G. Jackson
Chairman, Joint Military Operations Department

D. Shimkus 17 May 96
Faculty Advisor Date
Commander A. Shimkus NC USN

UNCLASSIFIED
Security Classification This Page

REPORT DOCUMENTATION PAGE

1. Report Security Classification: UNCLASSIFIED

2. Security Classification Authority:

3. Declassification/Downgrading Schedule:

4. Distribution/Availability of Report: DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

5. Name of Performing Organization: JOINT MILITARY OPERATIONS DEPARTMENT

6. Office Symbol: C

7. Address: NAVAL WAR COLLEGE
686 CUSHING ROAD
NEWPORT, RI 02841-1207

8. Title (Include Security Classification):
AMERICAN MILITARY READINESS FOR CHEMICAL AND BIOLOGICAL WARFARE: A CRITICAL VULNERABILITY (U)

9. Personal Authors:
MICHAEL D. McCARTEN CDR, MC, USN

10.Type of Report: FINAL

11. Date of Report: 14 JUNE 1996

12.Page Count: 23

13.Supplementary Notation: A paper submitted to the Faculty of the NWC in partial satisfaction of the requirements of the JMO Department. The contents of this paper reflect my own personal views and are not necessarily endorsed by the NWC or the Department of the Navy.

14. Ten key words that relate to your paper:
CHEMICAL WARFARE, BIOLOGICAL WARFARE, WEAPONS OF MASS DESTRUCTION, WMD, COUNTERPROLIFERATION, MILITARY READINESS

15.Abstract:
There has been a proliferation in the production and sale of chemical weapons, biological weapons and the missiles used to deliver them among potential adversaries of the U.S. As this proliferation continues, the likelihood of an attack against the U.S. is increasing. Despite NCA support for a counterproliferation initiative, deficiencies in readiness that existed at the time of the Persian Gulf War persist. Continued deficiencies are due to lack of prioritization at the level of the Joint Chiefs of Staff and the CINCs. These deficiencies constisute a critical vulnerability for the and as such, place the United States at risk of suffering a strategic defeat.

16.Distribution / Availability of Abstract:	Unclassified X	Same As Rpt	DTIC Users
17.Abstract Security Classification: UNCLASSIFIED			
18.Name of Responsible Individual: CHAIRMAN, JOINT MILITARY OPERATIONS DEPARTMENT			
19.Telephone: 841-[redacted] 6461		20.Office Symbol:	C

Security Classification of This Page Unclassified

ABSTRACT

There has been a proliferation in the production and sale of chemical weapons, biological weapons and the missiles used to deliver them among potential adversaries of the U.S. As this proliferation continues, the likelihood of an attack against the U.S. is increasing. Despite NCA support for a counter-proliferation initiative, deficiencies in readiness that existed at the time of the Persian Gulf War persist. Continued deficiencies are due to lack of prioritization at the level of the Joint Chiefs of Staff and the CINCs. These deficiencies constitute a critical vulnerability and as such, place the United States at risk of suffering a strategic defeat.

INTRODUCTION

The national security concerns of the United States have undergone significant changes in the years since the dissolution of the Soviet Union. In the past, the risk of nuclear attack was high with mutually assured destruction serving as the most effective defense. Today, the dominant security threat for the United States, as identified by the Clinton administration in the Report on the Bottom Up Review, is the proliferation of chemical and biological weapons and the missile systems designed to deliver them.[1] The extent of the chemical and biological weapons (CW/BW) threat, the response of the National Command Authority (NCA) to this threat, and how the geographic Commanders in Chief (CINCs) are impacted by this effort will be the focus of this paper.

While there has been tremendous legislative support given to CW/BW readiness, in the final analysis, a low level of funding, staffing and mission prioritization by the Joint Staff and the CINCs characterize the current state of affairs. As a result, the United States remains vulnerable to CW/BW attack and may sustain significant losses on the battlefield of the future. The impact of these findings is discussed in terms of operational art.

CURRENT STATE OF CW/BW PROLIFERATION

Currently 24 countries have either been confirmed to have or are suspected to have CW capabilities. Fourteen countries are believed to possess BW programs.[2] Iran, Iraq, Libya, Syria,

Cuba, China and North Korea are all potential U.S. adversaries who have active programs in CW and/or BW. Russia is suspected of maintaining an illegal capability of producing BW.[3,4] Thus it is seen that although the problem of CW/BW is global, it is focused in areas of instability and as such poses a significant threat to United States security.

Because many of the technical capabilities used in the production of these weapons have legitimate domestic and defensive uses, plausible deniability regarding offensive intent is possible for any state engaged in CW/BW production. For the United States, maintaining an accurate assessment of clandestine production is difficult since ingredients are readily accessible, the process is simple and a facility designed to produce BW can be established and disassembled in a matter of weeks, if not days.[5]

The proliferation and sale of missile systems designed to deliver CW/BW warheads poses an added security threat for the United States. Ballistic missiles, which have been the principal means of weapon delivery, continue to undergo modifications expanding their effective ranges of delivery.[6] North Korea's TAEPO DONG 2 missile, currently in development, will have an effective range of 4000 km.[7] Using such a system, Iran would be capable of targeting cities in southern Europe.

Cruise missiles are also undergoing a significant proliferation.[8,9] Although the effective range for cruise missiles is less than that for ballistic missiles, they can be

produced for 10-25% the cost and have the added benefit of pinpoint accuracy provided by Global Positioning System technology.[10] Defense against such missile systems is still in development and as such, inadequate missile defense could be construed as a vulnerability for the United States and its allies.

As was seen in the attack in Tokyo subway system in 1995, an additional area of concern relative to proliferation of CW/BW includes terrorist, paramilitary and insurgent groups. While most such groups do not possess the financial resources to produce sophisticated weapons, crude, assembed weapons are achievable, deployable and potentially devastating. The United States currently braces itself for terrorist activity at the Summer Olympics Games to be held in Atlanta this summer.[11,12]

Many developing nations view CW/BW as force multipliers which are easily obtained or produced. They are also effective as deterrents to regional aggression but have proven to be effective offensive weapons as well.[13] As such, the United States could find itself confronting third world or rogue state adversaries on a battlefield which would be asymetrically skewed by the inability of the United States to respond in kind. In such a setting, the United States could find itself at a strategic, operational and tactical disadvantage.[14]

The threat of CW/BW is very real and it is escalating. No longer is the United States dealing with a single foe who is engaged at the bargaining table and shares an interest in

disarmament. Rather, the threat is from a number of volatile, unpredictable states, some of which have already demonstrated their willingness to use such weapons. The hallmark of successful United States military operations of the future will be geographic CINCs going into battle with forces fully prepared and anticipating enemy assaults using CW/BW. Such a threat will exist whether engaged in a major regional contingency or an operation other than war.

CURRENT UNITED STATES RESPONSE TO CW/BW THREAT

The National Command Authority (NCA) has clearly stated its concern relative to CW/BW in its National Security and National Military Strategies.[15,16] Early in the current administration, then Secretary of Defense Les Aspin capsulized the concern regarding CW/BW when he said that these weapons "may directly threaten our forces in the field and, in a more subtle way, threaten the effective use of those forces."[17] DoD was committed to "ensure that our own force structure and military planning address the potential threat from weapons of mass destruction and missiles around the world."[18]

In a speech to the National Academy of Sciences in December 1993, Aspin established the Defense Counterproliferation Initiative (DCPI), and coined the term "counterproliferation" to be distinguished from the more common verbiage "nonproliferation".[19] In so doing, Aspin was acknowledging that, despite the reassurances of the post Cold War world, proliferation of CW/BW continued. In establishing the DCPI, he

was declaring that the United States was prepared to take active measures to thwart proliferative and offensive activities on the parts of adversaries. No longer would the U.S. passively await an attack.

The DCPI mandates improved weapons detection and destruction capabilities, enhanced ability to conduct military operations in the contaminated environment, increased precision in intercepting new delivery systems, improved capabilities to neutralize the consequences of attack and to deliver technologies to the fighting forces to accomplish the above named taskings.[20] It is clear that the thrust of the DCPI was to prepare the CINC for the CW/BW threat.

In response to the administration's increased commitment to counterproliferation, Congress passed the 1995 National Defense Authorization Act which directed the establishment of the Counter Proliferation Review Committee (CPRC). Comprised of the Secretary of Defense, Secretary of Energy, Director of the Central Intelligence Agency and the Chairman of the Joint Chiefs of Staff, this body was directed to " make recommendations relative to modifications in such programs required to address shortfalls in existing and programmed capabilities" to defend against CW/BW.[21] The CPRC has already been proven to be a key element in the counterproliferation effort.

A plethora of programs have been established to liaise between the CINCs and the Joint Staff to ensure the warfighting components' needs are met in preparing for counterproliferation

efforts.[22] Perhaps the most significant of these was the completion of the Chairman of the Joint Chiefs of Staff Counterproliferation Missions and Functions Study. As a result of this effort, the geographic CINC was given principal responsibility for CW/BW readiness. This change in tasking will be reflected in subsequent revisions of the Unified Command Plan.[23]

An immediately apparent shortcoming in this change in tasking however, is that the CINCs do not control the resources required to conduct the research and development or the training which are inherent in such an effort. They will be challenged to turn to the services for the achievement of these not insignificant goals in order that battle in the age of CW/BW can be waged effectively. Time will be the test of this arrangement.

To insure that the needs of the CINC were reflected in acquisition, the Joint Warfighting Capabilities Assessment (JWCA) Deterrence/Counterproliferation team was established in order to identify and prioritize those areas where mission enhancement was required.[24] The fourteen areas of counterproliferation capabilities prioritized by the CINCs are shown in Table 1.(Appendix A)

In addition to these specific areas of development, several broad categories of focus provide for further expansion of the counterproliferative effort. These include counterforce measures, active defense and passive defense. These areas will

be examined relative to the CINCs' readiness for the CW/BW threat.[25,26,27]

Counterforce programs focus on improving the capability of the CINC to strike at enemy forces prior to their deploying weapons against friendly forces. Relative to CW/BW weapons, counterforce efforts would concentrate on targeting, interdicting and destroying the weapons as well as destroying the supporting infrastructure.[28]

Despite the precision of U.S. weaponry during the Persian Gulf War, a deficiency discovered by enemy forces was the relative impenetrability of hardened underground bunkers.[29] As a result, many of our potential adversaries are today employing underground facilities to produce and store CW/BW[30], a tactical change the United States is having difficulty countering.[31]

Enhanced battlefield surveillance will also be a key aspect of the current CW/BW threat in the potentially clandestine circumstances under which an attack may be launched. The CINC must be capable of identifying and characterizing the CW/BW threat in an expeditious fashion for purposes of targeting, interdiction, planning CW/BW counterforce actions and battle-field damage assessment.[32]

Active defenses are those capabilities of the CINC designed to prevent enemy weapons from reaching their intended targets after they have been deployed. The challenge in developing an effective active defense is that it must counter those qualities of missile systems which make them desirable for our adversaries,

particularly their long distance range and their deployment from mobile launch platforms.[33] The development of such defensive missile systems is the topic of heated public debate and congressional testimony and may prove to be a contentious issue during the 1996 presidential election.[34,35,36,37]

An added challenge relative to active defense is that once an incoming weapon is intercepted and destroyed, the active agent contained in the warhead is released at the point of interdiction. Where the weapon is in its trajectory when it is destroyed will be of obvious political and military import. Efforts will need to be directed toward intercepting weapons while they remain over the launching territory, the so called "boost phase", a capability which may serve a deterrent as well as an active defense role.

An item of note relative to the "boost phase" initiative is that the funding for this defensive missile technology was cut by over 50% in fiscal 1995. The 1995 CRPC Report states "(t)he current funding level of $40 million is not adequate to address the boost phase intercept problem fully."[38] Such funding cuts may be indicative of a troubling trend.

One additional aspect of active defense which will plague the CINC is the issue of collateral damage. The lethality of these weaponized agents is not, in many cases, diminished by the application of a burst of heat as would occur during midair destruction. Hence, active defense measures may simply volatilize agent creating a situation with moral and political as

well as military implications.

Passive defense includes those measures which protect our forces against the effects of CW/BW, and would thus ensure the CINC has a full complement of resources capable of operating in the contaminated environment. Passive measures include those which protect the individual ground soldier, ships, as well as ground facility command centers. Agent detection and identification, protective masks and clothing, and medical measures taken before and after attack are all examples of passive defense measures and if employed in a timely fashion, can essentially neutralize the impact of CW/BW.[39]

During the Cold War, NATO forces became quite adept in conducting operations under conditions of CW/BW attack. "However, the U.S. Army prefers to avoid undertaking prolonged operations in protective chemical gear, owing to the severe limits such equipment places on effectiveness."[40] The wisdom of such logic must be called into question and again may be indicative of a more pervasive problem.

The post Cold War environment amplifies the importance of passive measures for the CINC and the dilemma he'll face in the future. Operations will surely be conducted throughout the world, often in unpredictable if not overtly hostile third world environments. The possibility of CW/BW will need to be considered in every estimate conducted, in every corner of the world and against every potential adversary.

The CINC must likewise be concerned with the coalition

nature of the force of the future. A coalition partner incapable of exercising effective passive defensive measures may prove a liability for the CINC and this will need to be calculated into any force planning.[41]

CW/BW READINESS DEFICIENCIES PERSIST

The experience of the United States military during the Persian Gulf War was sobering. Being generally unprepared for CW/BW attack, most U.S. forces received preparedness training in the desert during the six month build up of Operation Desert Shield. A General Accounting Office (GAO) report issued in January 1991 summarizes the overall dismal state of readiness that existed up to the time of the Persian Gulf War.[42]

A soon to be released GAO report, which serves as an effective follow up to the 1991 report, examines current CW/BW readiness and suggests that many of the deficiencies which existed prior to the Persian Gulf War persist. Based on data collected through February 1996, this report suggests that at the levels of the Joint Chiefs of Staff, CINCs, and individual unit commander, there is a low emphasis in funding, staffing, monitoring and mission priority in issues relating to CW/BW.[43]

None of the Army's crisis response divisions or early deploying Army reserve units were in full compliance with required stocking levels. Funds for such purchases were consistently diverted by unit commanders to meet other higher priorities.[44]

Deficiencies in training identified at the time of the

Persian Gulf War have been met with policy statements and doctrine revisions with little substantive improvement in skills acquisition. Despite the direction provided to the regional CINCs in October 1993 in the Universal Joint Task List issued by the Joint Staff specifying training requirements for CW/BW, only 15% of the joint exercises scheduled for fiscal 1996 contained any element regarding CW/BW. None of these exercises touched on the 23 essential skills identified as crucial to full readiness.[45]

Medical preparedness was similarly found to be lacking. Army medical units had 50-60% of required decontamination supplies available for deployment, much of it outdated. None of the forward deployable units possessed the types of collective shelters required to operate in the contaminated environment. In all cases of the units reviewed, less that 50% of the physicians had received anything but basic training in caring for casualties suffering from the effects of CW/BW and how to administer care in the contaminated environment. Basic skills such as donning masks were found to be deficient.[46]

This study concluded that the deficiencies in CW/BW preparedness persist despite the Persian Gulf experience, because of the inconsistent and low priority DoD places on such issues. This trend was apparent at the Joint Chiefs of Staff and the warfighting CINCs level. Funding for CW/BW issues has been cut 30% with further cuts scheduled. Key positions at the Joint Staff are being eliminated. Other mission types are receiving

priority at the CINC staff level.[47] Joint and CINC staffs identified higher priority taskings, low interest at senior levels, difficulty of performing tasks in protective gear and time consuming nature of CW/BW training as reasons for the relative inattention to CW/BW issues.[48]

This absence of readiness is unsettling. Through the establishment of the DCPI, the NCA has crafted a vision of the post Cold War world which maintains American military supremacy and diplomatic flexibility. If potential adversaries were certain to be major regional powers, the hope for negotiated settlement of disputes would be alive. The current world scene however, is replete with unpredictable if not unstable leaders who could not be relied upon to even enter negotiations, let alone negotiate in good faith.

If a third world power or rogue state with whom the United States had no effective diplomatic relations were to deploy CW/BW, the United States military would find itself ill prepared to protect itself or to respond satisfactorily. Under the stipulation of the 1972 Biological Weapons Convention and the soon to be ratified Chemical Weapons Convention, the United States would be incapable of responding in kind, a restraint which in itself may deflate the deterrent capability of American might.[49]

A rogue state might also penetrate American held space and release an agent surreptitiously so as to achieve plausible deniability. In such a scenario, the United States would sustain

unacceptable casualties without being able to respond.

CW/BW READINESS: A CRITICAL VULNERABILITY

Consideration of the CW/BW threat in terms of operational art demonstrates the urgency of the current situation. Clausewitz defines center of gravity as "the hub of all power and movement, on which everything depends."[50] To defeat an opponents center of gravity assures victory. Centers of gravity can be tangible, as in troop strength or armament capability, or they can be intangible, as in a country's leadership, its will to fight or public support for war.[51]

"Critical vulnerabilities" are those weaknesses which are directly related to the center of gravity and if attacked, would permit access to an adversary's center of gravity. Therefore, the attack against an opponent's critical vulnerabilities would gain access to the center of gravity and would thus constitute a strategy for victory.[52]

As has been clearly demonstrated with the American experience in Viet Nam, and in the aftermath of the Somali ambush, the American public will not tolerate needless casualties. As such, a chemical or biological strike resulting in large numbers of American casualties could decimate the public will and thus negate policy intentions held by the NCA, that is, an adversary could achieve a strategic success. While an American response to such an attack would be a certainty, a response may be muted or restrained lacking firm evidence of a

an adversary could achieve a strategic success. While an American response to such an attack would be a certainty, a response may be muted or restrained lacking firm evidence of a perpetrator or limited by treaty.

For the purposes of the present discussion, the current American military vulnerability to CW/BW attack constitutes a critical vulnerability, exploitation of which would permit access to the intangible center of gravity, the public will, and would thus permit an opponent the opportunity to achieve a strategic victory. It is unlikely of course, that such a victory would be in military terms. However, as recent history has demonstrated, military might does not guarantee success.

It is of a critical urgency then that the United States achieve a satisfactory capability to prevent, deter, protect against and neutralize the threat of CW/BW attack. The administrative support for this effort has been forthcoming but the firm commitment to CW/BW readiness at the Joint Staff and CINC levels has been hampered by excessive mission burden, and by shortages in staffing and funding.

The technologies discussed in this paper are mostly developmental. Acceleration of the fielding of these systems is of the utmost urgency. Only when the United States can effectively defend against CW/BW will the United States be capable of devaluing the possession of these weapons, the first step required to achieve their ultimate elimination.

CONCLUSION

In light of the current analysis, it is apparent that the readiness of American military forces to defend against and respond to a CW/BW attack is deficient. The threat is expanding daily. Its very nature poses a significant strategic, operational and tactical thrteat to United States and its allies. Despite apparent support provided by the NCA, efforts to mount an effective counterproliferative capability on the battlefield are fraught with apparent inefficiencies and inadequacies. This is a result of low prioritization relative to other warfighting needs, including staffing and funding shortages. While it is the CINC who is ultimately charged with combatting CW/BW and who is responsible to ensure readiness, the acquisition of the necessary capabilities he will need to accomplish this readiness is out of his hands and as such potentially derails the counterproliferation effort. This vulnerability to the effects of CW/BW, a critical vulnerability, place the United States in the dubious position of sustaining a strategic setback at the hands of a second rate power.

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DOCUMENT 2

Chemical and Biological Defense: Emphasis Remains Insufficient to Resolve Continuing Problems

AD-A306 901

March 1996

United States General Accounting Office Washington, DC

United States General Accounting Office

GAO

Report to Congressional Requesters

March 1996

CHEMICAL AND BIOLOGICAL DEFENSE

Emphasis Remains Insufficient to Resolve Continuing Problems

GAO/NSIAD-96-103

GAO

United States
General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

B-258889

March 29, 1996

The Honorable Herbert H. Bateman
Chairman
The Honorable Norman Sisisky
Ranking Minority Member
Subcommittee on Military Readiness
Committee on National Security
House of Representatives

U.S. forces face an increasing number of potential enemies capable of waging chemical and biological warfare. Experiences during the Gulf War and subsequent Department of Defense (DOD) studies suggest that U.S. forces may not be sufficiently prepared to survive and fight in a chemically or biologically contaminated environment. In accordance with the House National Security Committee report on the National Defense Authorization Act for Fiscal Year 1996, we evaluated U.S. chemical and biological warfare defense capabilities.

(2) the risks associated with reliance on post-mobilization activities to overcome deficiencies in chemical and biological readiness. Post-conflict studies confirmed that U.S. forces were not fully prepared to defend against Iraqi use of chemical or biological weapons and could have suffered significant casualties had they been used. Units and individuals often arrived in theater without needed equipment, such as protective clothing and adequate chemical and biological agent detectors. Active and reserve component forces required extensive chemical and biological training before and after arrival in Southwest Asia. Medical readiness problems included inadequate equipment and training. Biological agent vaccine stocks, and policies and procedures for their use, were also inadequate. While post-mobilization and in-theater activities increased readiness, equipment and training problems persisted to varying degrees throughout the conflict. Complacency and the absence of command emphasis on chemical and biological defense prior to deployment were among the root causes of this lack of preparedness. We previously reported on these problems in May 1991.[2]

Since the Gulf War, Congress has expressed concern about the proliferation of chemical and biological weapons and the readiness of U.S. forces to operate in a contaminated environment. In November 1993, the National Defense Authorization Act for Fiscal Year 1994 (P. L. 103-160) directed the Secretary of Defense to take specific actions designed to improve chemical and biological defense and to report annually to Congress on the status of these efforts.

Results in Brief

Units designated for early deployment today continue to face many of the same problems experienced by U.S. forces during the Gulf War. Activities undertaken by DOD since the war are improving the readiness of U.S. forces to operate in a chemically or biologically contaminated environment. However, equipment, training, and medical shortcomings persist and are likely to result in needless casualties and a degradation of U.S. war-fighting capability.

Today, chemical and biological defense activities at all levels (from the Joint Staff to individual Army and Marine units) tend to continue to receive a lower level of emphasis than other high-priority activities, such as performing traditional operational mission tasks. This lower emphasis is seen in the funding, staffing, monitoring, and mission priority given to

[2]Chemical Warfare: Soldiers Inadequately Equipped and Trained to Conduct Chemical Operations (GAO/NSIAD-91-197, May 29, 1991).

chemical and biological defense activities. Army officials contend that increased operational deployments coupled with reduced forces and budgetary constraints force commanders to make decisions regarding which aspects of operational preparedness to emphasize and those for which they are willing to accept increased risk. Thus, many commanders have accepted a level of chemical and biological defense unpreparedness and believe the resources currently devoted to this area are appropriate, given other threats and current budgetary constraints. Activities to equip, train, and otherwise prepare U.S. forces to operate in a contaminated environment have therefore received insufficient attention to resolve many continuing problems.

Problems Experienced in the Gulf War Remain

Although DOD is taking steps to improve the readiness of U.S. ground forces to conduct operations in a chemical or biological environment, serious weaknesses remain. Many early deploying active and reserve units do not possess the amount of chemical and biological equipment required by regulations, and new equipment development and procurement are often proceeding more slowly than planned. Many units are not trained to existing standards, and military medical capability to prevent and treat casualties on a contaminated battlefield is very limited.

Early Deploying Units Lack Required Equipment

During the Gulf War, units and individuals often deployed without all the chemical and biological detection, decontamination, and protective equipment they needed to operate in a contaminated environment. For example, some units did not have sufficient quantities or the needed sizes of protective clothing, and chemical detector paper and decontamination kits in some instances had passed expiration dates by as much as 2 years. These shortages in turn caused logistical problems, such as the rapid depletion of theater equipment reserves, and required extraordinary efforts by logisticians and transporters to rectify the situation during the 6-month interval between deployment and the initiation of major combat. Had chemical or biological weapons been used during this period, some units might have suffered significant, unnecessary casualties.

To prevent this problem from recurring in future conflicts, in 1993 the U.S. Forces Command (FORSCOM) revised its requirements regarding the amount of chemical and biological defense equipment early deploying active and reserve units are required to store on hand.[3] This action was

[3]FORSCOM is responsible for training and equipping all Army forces located in the continental United States. The revised requirements are contained in FORSCOM Regulation 700-2 (June 15, 1993).

intended to ensure that these units would have sufficient equipment on hand upon deployment until in-theater logistical support could be established.

We found that neither the Army's approximately five active divisions composing the crisis response force (divisions with mobilization to deployment requirements of less than 30 days) nor any of the early deploying Army reserve units we visited were in full compliance with the new stock level requirements. All had shortages of various types of critical equipment. For example, three of the active divisions had 50 percent or greater shortages of protective clothing (battle dress overgarments), and shortages of other critical items (such as protective boots, gloves, hoods, helmet covers, mask filters, and decontamination kits) ranged from no shortage to an 84-percent shortage depending on the unit and the item concerned.

Shortages in on-hand stocks of this equipment were often exacerbated by poor inventorying and reordering techniques, shelf-life limitations, and difficulty in maintaining appropriate protective clothing sizes. For example, none of the active units we visited had determined how many and what sizes of chemically protected overgarments were needed. FORSCOM officials told us the Army's predetermined standard formula for the numbers of different clothing sizes needed by the average unit was often inaccurate, particularly for support units that are likely to have larger percentages of female soldiers. Furthermore, shortages of chemical protective clothing suits are worsening because most of the active divisions we visited had at least some of these items on hand with 1995 expiration dates. Unit stock levels are also being affected by problems with the availability of appropriate warehouse space at most of the installations we visited.

Army officials at FORSCOM and in the active units we visited were aware of these shortages. They said that the operation and maintenance funds normally used to purchase this equipment had been consistently diverted by unit commanders to meet other higher priority requirements such as base operating costs, quality-of-life considerations, and costs associated with other-than-war deployments such as those to Haiti and Somalia. Our review of FORSCOM financial records showed that while the operation and maintenance account included funds budgeted for chemical and biological training and equipment, very little had actually been spent on equipment during fiscal year 1995 at the FORSCOM units we visited. Army records were inadequate to determine for what purposes the diverted funds had been

used except by reviewing individual vouchers. We did not attempt to review these because of the time and resources such a review would require.

Army officials acknowledged that increasing operation and maintenance funding levels was unlikely to result in increased unit chemical equipment stocks unless in operation and maintenance funding increases are specifically designated for this purpose. Numerous other activities also dependent on operation and maintenance funding are being given a higher priority than chemical defense equipment by all the early deploying active Army divisions we visited. The cost of purchasing this equipment is relatively low. Early deploying active divisions in the continental United States could meet current stock requirements for an additional cost of about $15 million. However, some may need to acquire additional warehouse storage space for this equipment. FORSCOM officials told us that due to a variety of funding and storage problems, they were considering decreasing chemical defense equipment contingency stock requirements to the level needed to support only each early deploying division's ready brigade and relying on depots to provide the additional equipment needed on a "just-in-time" basis before deployment.

FORSCOM officials told us that other potential solutions were also being considered, such as funding these equipment purchases through procurement rather than operation and maintenance accounts, or transferring responsibility for purchasing and storing this material on Army installations to the Defense Logistics Agency. It is unclear to what extent this and other alternatives might be effective in providing the needed equipment prior to deployment.

Research and Development Progress Is Slower Than Planned

At the beginning of the Gulf War, U.S. forces were vulnerable because the services lacked such things as (1) effective mobile systems for detecting and reporting chemical or biological agents; (2) a decontaminate solution suitable for use in sensitive interior areas of aircraft, ships, and vehicles; and (3) a suitable method for decontaminating large areas such as ports and airfields. Protective clothing was problematic because it was heavy, bulky, and too hot for warm climates.

In response to lessons learned in the Gulf War and subsequent congressional guidance, DOD has acted to improve the coordination of chemical and biological doctrine, requirements, research, development, and acquisition among DOD and the military services. During 1994 and

1995, DOD planned and established the Joint Service Integration and Joint Service Materiel Groups, which are overseen by a single office within DOD—the Assistant Secretary of Defense (Atomic Energy/Chemical and Biological Matters). The Joint Service Integration Group is to prioritize chemical and biological research efforts and establish a modernization plan, and the Joint Service Materiel Group is to develop the research, development, acquisition, and logistics support plans.

These groups have begun to implement the requirements of Public Law 103-160. However, progress has been slower than expected. At the time of our review, the Joint Service Integration Group expected to produce its proposed (1) list of chemical and biological research priorities and (2) joint service modernization plan and operational strategy during March 1996. The Joint Service Materiel Group expects to deliver its proposed plan to guide chemical and biological research, development, and acquisition in October 1996. It is unclear whether or when DOD will approve these plans. However, fiscal year 1998 is the earliest that DOD can begin their formal implementation if they are quickly approved. Consolidated research and modernization plans are important for avoiding duplication among the services and otherwise achieving the most effective use of limited resources. DOD officials told us progress by these groups has been adversely affected by personnel shortages and other assigned tasks.

DOD's efforts to develop and improve specific equipment have had mixed results. The Fox mobile reconnaissance system, fielded during the Gulf War, features automated sampling, detection, and warning equipment. However, due to budgetary constraints, DOD approved the acquisition of only 103 of the more than 200 Fox systems originally planned. Early deploying Army mechanized and armored divisions have been assigned 6 Fox vehicles each, the Marine Corps has 10, and virtually all the remainder have been assigned to a chemical company from which they would be assigned as needed in the event of a conflict. Our discussions with Army officials revealed concerns about the adequacy of assigning only 6 Fox vehicles per division. They said a total of 103 Fox vehicles might be insufficient to meet needs if chemical and/or biological weapons are used in two nearly simultaneous regional conflicts, particularly until the Army's light divisions and the Marine Corps are equipped with a planned smaller and lighter version of a reconnaissance system. In January 1996, DOD also began to field the Biological Integrated Detection System, a mobile system for identifying biological agents, and plans to field 38 by September 1996.

Other programs designed to address critical battlefield deficiencies have been slow to resolve problems. DOD's 1995 Annual Report to Congress identified 11 chemical and biological defense research goals it expected to achieve by January 1996. Of these, five were met on time. Of the remaining goals, two will not be achieved by 1997, and it is unclear when the remainder will be achieved. An effort ongoing since 1987 to develop a less corrosive and labor-intensive decontaminate solution is not expected to be completed until 2002. Work initiated in 1978 to develop an Automatic Chemical Agent Alarm (designed to provide visual, audio, and command-communicated warning of chemical agents) remains incomplete, and efforts to develop wide-area warning and decontamination capabilities are not expected to be achieved until after the year 2000.

Army and Marine Forces Remain Inadequately Trained for Effective Chemical and Biological Defense

Army and Marine Corps regulations require that individuals be able to detect the presence of chemical agents, quickly put on their protective suits and masks, decontaminate their skin and personal equipment, and evaluate casualties and administer first aid. Units must be able to set alarms to detect agents, promptly report hazardous agent attacks to higher headquarters, mark and bypass contaminated areas, and remove hazardous agents from equipment and vehicles. Commanders are required to assess their units' vulnerability to chemical or biological attacks, determine the level of protection needed by their forces, implement a warning and reporting system, employ chemical units to perform reconnaissance and decontamination operations, and ensure that adequate measures are in place to evacuate and treat casualties. Training for these tasks is accomplished through a variety of live and simulated exercises conducted at units' home stations and at combat training centers such as the Army's National Training Center at Fort Irwin, California, and the Marine Corps Air Ground Combat Center at 29 Palms, California.

Since the Gulf War, the services have acted to improve their chemical and biological training. They (1) issued policy statements on the importance of chemical and biological readiness, (2) revised doctrinal guidance and training regulations, and (3) collocated chemical defense training for all four services at the Army's Chemical School, Fort McClellan, Alabama.[4] Commanders were instructed to ensure that their units were fully trained to standard to defend and sustain operations against battlefield chemical and biological hazards. Further, they were instructed that chemical and

[4]The Defense Secretary's Commission on Base Realignments and Closures has recently recommended relocating the U.S. Army Chemical School to Fort Leonard Wood, Missouri.

biological training must be fully integrated into unit exercises and must test the capability of commanders, staffs, and units to perform their mission under chemical and biological conditions.

In spite of these efforts, many problems of the type encountered during the Gulf War remain uncorrected, and U.S. forces continue to experience serious training-related weaknesses in their chemical and biological proficiency. In a series of studies conducted by the Army from 1991 to 1995, the Army found serious weaknesses at all levels in chemical and biological skills. For example, a 1993 Army Chemical School study found that a combined arms force of infantry, artillery, and support units would have extreme difficulty in performing its mission and suffer needless casualties if forced to operate in a chemical or biological environment. The Army concluded that these weaknesses were due to the force being only marginally trained to operate in a chemical and biological environment. Many of these problems had been identified a decade ago. For example, the Army found similar problems in three other studies of mechanized and armored units conducted by the Chemical School in 1986, 1987, and 1989.

Our analysis of Army readiness evaluations, trend data, and lessons learned completed from 1991 to 1995 also showed serious problems. At the individual, unit, and commander level, the evaluations showed a wide variety of problems in performing basic tasks critical to surviving and operating in a chemical or biological environment. These problems included (1) inability to properly don protective masks, (2) improper deployment of detection equipment, (3) inability to administer first-aid to chemical or biological casualties, (4) inadequate planning on the evacuation of casualties exposed to chemical or biological agents, and (5) failure to integrate chemical and biological issues into operational plans. More detailed information on these problems is contained in appendixes I and II.

Our work showed that the Marine Corps also continued to be affected by many of the same problems experienced during the Gulf War. Marine Corps 1993 trendline data from its combat training center at 29 Palms, California, showed that (1) submission of chemical and biological warning reports were not timely, (2) units and individuals were inexperienced with detection equipment, and (3) units did not properly respond to a chemical attack, issue alarms to subordinate elements, and follow proper unmasking techniques following a chemical attack.

Joint Exercises Include Little Chemical or Biological Defense Training

Current U.S. military strategy is based on joint air, land, sea, and special operations forces operating together in combat and noncombat operations. The Chairman of the Joint Chiefs of Staff (CJCS) Exercise Program is the primary method DOD uses to train its commanders and forces for joint operations. Our analysis of exercises conducted under the program showed that little chemical or biological training was being done.

In October 1993, the Joint Staff issued the Universal Joint Task List for the regional commanders in chief (CINC) and the services to use to help define their joint training requirements. The list includes 23 chemical and biological tasks to be performed, such as gathering intelligence information on the enemy's chemical and biological warfare capabilities, assessing the effects of these agents on operations plans, and performing decontamination activities. In fiscal year 1995, 216 exercises were conducted under the CJCS program. These were planned, conducted, and evaluated by each CINC.

Our analysis of the exercises conducted by four major CINCs (U.S. Atlantic, Central, European, and Pacific commands) in fiscal year 1995 and planned for fiscal year 1996 showed little joint chemical or biological training is being conducted. Overall, these CINCs conducted at least 70 percent of the total number of CJCS exercises held in fiscal year 1995 and planned for fiscal year 1996. However, only 10 percent of the CJCS exercises they conducted in 1995 and 15 percent of those to be conducted in fiscal year 1996 included any chemical or biological training. Of the exercises conducted, none included all 23 tasks, and the majority included less than half of these tasks. Appendixes III and IV show the amount of joint training being conducted by these CINCs.

Two reasons account for the little amount of joint chemical and biological training. First, notwithstanding Joint Staff guidance to CINCs on the need to train for chemical and biological warfare threats, the CINCs generally consider chemical and biological training and preparedness to be the responsibility of the individual military services. Second, most of the CINCs have assigned a lower priority to chemical and biological issues than others that they feel more directly relate to their mission. In this regard, CINCs and other major commanders have made a conscious decision to better prepare for other, more likely threats and to assume greater risk regarding chemical and biological defense.

Biological Agent Vaccine Stocks and Immunization Plans Remain Inadequate

For many years, DOD has maintained a medical research and development program for biological defense. However, at the time of the Gulf War, the United States had neither fielded equipment capable of detecting biological agents nor stocked adequate amounts of vaccine to protect the force. When the Gulf War started, DOD also had not established adequate policies and procedures for determining which vaccines needed to be administered, when they were to be given, and to whom. According to DOD officials, this caused much DOD indecision and delay and resulted in U.S. forces being administered varying types of vaccines about 5 months after they began arriving in theater and only a month or so before the major ground offensive began. Sufficient protection was not provided by the time the offensive began either, since virtually all biological agent vaccines require a minimum of 6 to 12 weeks or longer after immunization to become effective.

Since the Gulf War, DOD has increased the attention given to biological warfare defense. DOD consolidated the funding and management of several biological warfare defense activities, including vaccines, under the new Joint Program Office for Biological Defense. In November 1993, DOD established the policy, responsibilities, and procedures for stockpiling biological agent vaccines and determined which personnel should be immunized and when the vaccines should be administered. This policy specifically states that personnel assigned to high-threat areas and those predesignated for immediate contingency deployment to these areas (such as personnel in units with deployment dates up to 30 days after mobilization) should be vaccinated in sufficient time to develop immunity prior to deployment. DOD has also identified which biological agents constitute critical threats and determined the amount of vaccine that should be stocked for each. At present, the amount of vaccines stocked remains insufficient to protect the force.

The Joint Chiefs of Staff and other high-ranking DOD officials have not yet approved implementation of the established immunization policy. No decision has yet been made on which vaccines to administer, nor has an implementation plan been developed. DOD officials told us the implementation plan should be developed by March 1996, but this issue is highly controversial within DOD, and it is unclear whether the implementation plan will be approved and carried out. Until such an implementation plan is developed and approved and immunizations are given, existing vaccines cannot provide the intended protection from biological agents for forces already stationed in high-threat areas and

those designated for early deployment if a crisis occurs and biological agents are used.

Problems also exist with regard to the vaccines available to DOD for immunization purposes. Only a few biological agent vaccines have been approved by the Food and Drug Administration (FDA). Many remain in Investigational New Drug (IND) status. Although IND vaccines have long been safely administered to personnel working in DOD vaccine research and development programs, the FDA usually requires large-scale field trials in humans to demonstrate new drug safety and effectiveness before approval. DOD has not performed such field trials because of the ethical and legal considerations involved in deliberately exposing humans to toxic or lethal biological agents; nor has it effectively pursued other means of obtaining FDA approval for IND vaccines. IND vaccines can therefore now be administered only under approved protocols and with written informed consent.

During the Gulf War, DOD requested and received a waiver from the FDA requirement for written informed consent since this was a contingency situation. If DOD intends to use vaccines to provide protection against biological agents to personnel already assigned to high-threat areas or designated for rapid deployment, then it needs to make the required decisions for proceeding with immunizations and either using IND vaccines or obtaining FDA approval for them. DOD officials told us they hoped to acquire a prime contractor during 1996 to subcontract vaccine production with the pharmaceutical industry and take the actions needed to obtain FDA approval for existing IND vaccines.

Army Medical Units Often Lack Chemical and Biological Defense Equipment

Medical units assigned to support the early deploying Army divisions we visited often lacked certain types of equipment needed to treat casualties in a chemically or biologically contaminated environment. For example, these units are authorized chemical patient treatment sets and patient decontamination kits that contain items such as suction apparatuses and airways, aprons, gloves, scissors, and drugs and chemicals for treating or decontaminating casualties. Overall, the medical units we visited had on hand only about 50 to 60 percent of their authorized patient treatment kits and patient decontamination kits. Some units we visited had not been issued any of these kits. Further, our inspection of some kits showed that they were missing critical components, such as drugs used for treating chemical casualties. Army officials said that the shelf life of these items

had expired and that operation and maintenance funds were not available to replace them.

Forward medical support for combat units, such as battalion aid stations and mobile army surgical hospitals, need to be capable of operating in contaminated environments. However, none of the medical units we visited had any type of collective shelter that would enable them to provide such treatment. Army officials acknowledged that the lack of shelters would virtually prevent any forward area treatment of casualties, and would cause greater injury and death rates. They told us that older versions of collective shelters developed to counter the Soviet threat were unsuitable, unserviceable, and no longer in use. While new shelters—both a field hospital version and a small mobile version mounted on a vehicle—are in development, they are not expected to be available for initial issuance to units until at least fiscal years 1997 and 1998. Furthermore, Army officials told us that the Army plans to limit issuance of the mobile shelters to about 90 percent of the crisis response force, has canceled plans for a tracked version for mechanized and armored divisions, and might not purchase the currently planned version due to its funding priority.

Methods to Ensure That Medical Personnel Receive Chemical and Biological Training Need Improvement

Military physicians assigned to medical units supporting early deploying Army divisions need to be trained to treat and manage casualties in a chemical or biological environment. All Army physicians attend the Medical Officer Basic Course and receive about 44 hours of training on nuclear, biological, and chemical (NBC) topics. The Officer Advanced Course provides another 40 hours of instruction for medical officers when they reach the rank of major or lieutenant colonel, but is optional. Also optional, the Management of Chemical and Biological Casualties Course provides 6-1/2 days of classroom and field instruction to military health care providers and is designed to establish the essential skills needed to save lives, minimize injury, and conserve fighting strength in a chemical or biological warfare environment. During Operation Desert Storm, this course was provided on an emergency basis to medical units already deployed to the theater. These three courses constitute the bulk of formal military medical training specifically oriented toward chemical and biological warfare casualty treatment, with some additional training provided through other shorter courses.

Our examination showed that of the physicians either currently assigned to medical units in selected early deploying Army divisions or designated

to report to these units at deployment, only a limited number had completed the medical officer advanced and casualty management courses. The percentage of physicians that had attended the advanced course ranged from 19 to 53 percent, while from 3 to 30 percent had attended the casualty management course. Army medical officials told us that the demands of providing peacetime medical care to military personnel and their dependents often prevented attendance at these courses. Furthermore, the Army had made no effort to monitor whether these physicians had received this training, and attendance of the casualty management course was neither required nor targeted toward physicians assigned to early deploying units or otherwise needing this training.

We also found little or no training is being conducted on casualty decontamination from chemical or biological agents at most of the early deploying divisions and medical units we visited. There was usually confusion among these units regarding who was responsible for performing this task. According to Army doctrine, tactical units are expected to conduct initial casualty decontamination before their evacuation or arrival at forward medical treatment facilities. Army lessons learned from Operation Desert Storm noted that some units lacked understanding of the procedures and techniques used to decontaminate casualties. This situation had not been corrected at the time of our review.

Problems Remain Due to Limited Emphasis on Chemical and Biological Defense

Although DOD has taken actions to improve chemical and biological defense since the Gulf War, DOD's emphasis has not been sufficient to resolve many serious lingering problems. Our measurement of key indicators—DOD funding, staffing, mission priority, and monitoring—showed that chemical and biological defense tends to be relegated a lower level of priority than other threat areas.

Funding

Historically, DOD has allocated less than 1 percent of its total budget to chemical and biological defense. Annual funding for this area has decreased by over 30 percent in constant dollars, from approximately $750 million in fiscal year 1992 to $504 million in fiscal year 1995. Funding for chemical and biological defense activities could decrease further if the Secretary of Defense agrees to a recent proposal by the Joint Staff. In response to a recent Joint Staff recommendation to reduce counterproliferation funding over $1 billion over the next 5 years, DOD identified potential reductions of approximately $800 million. DOD officials told us that, if implemented, this reduction would severely impair planned

chemical and biological research and development efforts and reverse the progress already made in several areas. For example, procurement of the Automatic Chemical Agent Alarm would be delayed well into the next century, as would the light NBC reconnaissance system.

At the time we completed our work, DOD officials told us that DOD was considering reducing the amount of the proposed funding reduction to about $33 million, resulting in a far less serious impact on chemical and biological warfare programs. However, we believe that the limited funding devoted to chemical and biological defense, the tendency to reduce this funding to avoid cuts in other operational areas, and the tendency of commanders to divert operation and maintenance funding budgeted for chemical and biological defense is indicative of the lower priority often given this area.

Staffing

Chemical and biological defense activities were frequently understaffed and heavily tasked with other unrelated duties. At the CINC and military service levels, for example, chemical officers assigned to CINC staffs were often heavily tasked with duties not related to chemical and biological defense. At FORSCOM and U.S. Army III Corps headquarters, chemical staff positions were being reduced, and no chemical and biological staff position exists at the U.S. Army Reserve Command. Finally, according to DOD officials, the Joint Service Integration and Joint Service Materiel Groups (the groups charged with overseeing research and development efforts for chemical and biological equipment) have made less progress than planned due to staffing shortages and other assigned tasks.

Mission Priority

The priority given to chemical and biological defense matters varied widely. Most CINCs appear to assign chemical and biological defense a lower priority than other threats. CINC staff members told us that responsibility for chemical and biological defense training was primarily a service matter, even though the Joint Staff has tasked the CINCs with ensuring that their forces are trained in certain joint chemical and biological tasks. Several high-ranking DOD officials told us that U.S. forces still face a limited, although increasing, threat of chemical and biological warfare.

At Army corps, division, and unit levels, the priority given to this area depended on the commander's opinion of its relative importance. For example, one early deploying division we visited had an aggressive system

for chemical and biological training, monitoring, and reporting. At another, the division commander made a conscious decision to emphasize other areas due to limited resources and other more immediate requirements, such as other than war deployments and quality of life considerations. As previously discussed, Army medical officials told us that the demands of providing peacetime medical care to military personnel and their families often interfered with medical training oriented toward combat-related subjects such as chemical and biological casualties.

Officials from Army major commands, corps, divisions, and individual units said that chemical and biological defense skills not only tended to be difficult to attain and highly perishable but also were often given a lower priority than other areas for the following reasons:

- too many other higher priority taskings,
- low levels of monitoring or interest by higher headquarters,
- the difficulty of performing tasks in cumbersome and uncomfortable protective gear,
- the time-consuming nature of chemical training,
- heavy reliance on post-mobilization training and preparation, and
- the perceived low likelihood of chemical and biological warfare.

Monitoring

The lower emphasis given to chemical and biological matters is also demonstrated by weaknesses in the methods used to monitor its status. DOD's current system for reporting overall readiness to the Joint Staff is the Status of Resources and Training System (SORTS). This system measures the extent to which individual service units possess the required resources and are trained to undertake their wartime missions. SORTS was established to provide the current status of specific elements considered essential to readiness assessments, such as personnel and equipment on hand, equipment condition, and the training of operating forces. The SORTS elements of measure, "C" ratings that range from C-1 (best) to C-4 (worst), are probably the most frequently cited indicator of readiness in the military.

In a 1993 effort to improve the monitoring of chemical and biological defense readiness, DOD required units from all services to assess their equipment and training status for operations in a contaminated environment and report this data as a distinct part of SORTS. DOD's 1994 and 1995 annual reports to Congress on nuclear, biological, and chemical warfare defense reported the continued lack of an adequate feedback

mechanism on the status of chemical and biological training, equipment, and readiness.

We found that the effectiveness of SORTS for evaluating unit chemical and biological readiness is limited. While the current report requires unit commanders to report shortages of critical chemical or biological defense equipment, it leaves the determination of which equipment is critical up to the commander. The requirements also allow commanders to subjectively upgrade their overall SORTS status, regardless of their chemical and biological status. For example, one early deploying active Army division was rated in the highest SORTS category (C-1) despite rating itself in the lowest category (C-4) for chemical and biological equipment readiness. In addition, SORTS does not require reporting of some critical unit and individual equipment items if they are being stored at corps, rather than unit level, and SORTS reports are sometimes inaccurate due to poor equipment inventorying techniques.

Furthermore, while individual units must fill out these reports, divisions are not required to do so. FORSCOM officials told us that most of the early deploying active Army divisions did not complete summaries of this report for at least 4 months in 1995 and that FORSCOM did not monitor these reports for about 6 months in 1995 due to a lack of personnel and other priorities. FORSCOM officials told us they normally performed only limited monitoring of unit chemical and biological readiness and relied mostly on unit commanders to report any problems. The U.S. Army Reserve Command does not have an office or individual assigned to monitor reserve units' chemical and biological equipment and training status.

With the exception of SORTS, the monitoring of chemical and biological readiness varied widely. At the CINC level, virtually no monitoring was being done. None of the CINCs we visited required any special reports on chemical or biological matters or had any special monitoring systems in place. At lower levels, monitoring was inconsistent and driven by the commander's emphasis on the area. At both division and corps levels, monthly briefings, reports, and other specific monitoring of chemical and biological readiness were sometimes required and sometimes not, depending on the commander's view of the importance of this area.

Other methods the Army uses to monitor chemical and biological proficiency are (1) after-action and lessons-learned reports summarizing the results of operations and unit exercises at the Army's combat training centers and (2) operational readiness evaluations. The effectiveness of

these tools is hindered by the varying amounts of chemical and biological training included in unit rotations at the combat training centers and the frequent lack of realism under which chemical and biological conditions are portrayed. Unit commanders influence the amount of chemical and biological training to be included in exercises at the centers and how and when it will be used in the exercises. In some cases, Army officials said that these exercises often include little chemical and biological training and that in others it is conducted separately from more realistic combat training.

Operational readiness evaluations (ORE), on the other hand, were more standardized in the areas of chemical and biological proficiency that were assessed. FORSCOM used OREs to obtain external evaluations of active, reserve, and National Guard unit readiness and to identify areas needing improvement. These evaluations focus on unit ability to perform its wartime missions prior to mobilization and deployment. OREs consist of a records check of personnel, logistics, training, and mobilization data and an assessment of a unit's ability to perform critical collective and individual mission tasks, including chemical and biological defense tasks. However, since the second quarter of fiscal year 1995, the Army has discontinued OREs at all active units and certain Army National Guard units.

Marine Corps monitoring of chemical and biological matters was more extensive than the Army's. The Marine Corps conducts standardized Operational Readiness and Commanding General Inspections, Combat Readiness Evaluation Programs, and Marine Corps Combat Readiness Evaluations that assess chemical and biological proficiency. The Corps also requires monthly reports to division commanders that assess home station training in several specified chemical and biological areas. However, the effectiveness of some of its evaluation tools is also questionable for some of the same reasons as those we found for the Army.

As discussed earlier, Marine Corps trend data and lessons-learned information from its main combat training center at 29 Palms, California, showed serious weaknesses in units' chemical and biological proficiency. Despite these deficiencies, in 1994 the Marine Corps decided, as a result of downsizing, to discontinue comprehensive exercises and evaluations of unit chemical and biological defense proficiency at the 29 Palms combat training center and concentrate instead on fire support and maneuver training. Marine chemical and biological training is therefore now largely

relegated to the home station training exercises and evaluations mentioned above.

Like the Army, the Marine Corps now relies on unit commanders to determine the amount of chemical and biological training needed at their home stations based on their assessments of their units' capabilities and the evaluations described above. The commander's primary source of determining unit chemical and biological readiness is the Operational Readiness Inspection. Our analyses of these inspections conducted in 1994 and 1995 for the 2d Marine Expeditionary Force showed that units were trained with a few minor deficiencies. The other evaluations for the same time period showed little discussion of chemical and biological proficiency. Marine Corps officials stated that unless problems are found, these programs would not include discussions of these matters. In the few instances where the evaluations discussed chemical and biological matters, they for the most part concluded that the units were trained. However, Marine Corps officials told us that these home station evaluations do not expose units to the same training rigor and battlefield conditions as exercises conducted at 29 Palms and therefore are questionable indicators of actual unit chemical and biological defense proficiency. Thus, the extent that the Marine Corps has corrected the chemical and biological problems it encountered during Operation Desert Storm and since is uncertain.

Conclusions

Although DOD has improved chemical and biological defense capability since the Gulf War, many problems of the type experienced during this war continue to exist. This is in large part due to the inconsistent but generally lower priority DOD, and especially the Joint Chiefs of Staff and the warfighting CINCs, assign chemical and biological defense relative to other priorities. These problems are likely to continue given current reductions in military funding and the limited emphasis placed on chemical and biological defense, unless the Secretary of Defense and the CJCS specifically assign a higher priority to this area. Until these problems are resolved, U.S. forces are likely to encounter operational difficulties and could incur needless casualties if attacked with chemical or biological weapons.

Recommendations

We could not determine whether increased emphasis on chemical and biological warfare defense is warranted at the expense of other priorities. This is a matter of DOD's military judgment and congressional funding priorities.

In view of the increasing chemical and biological warfare threat and the continuing weaknesses in U.S. chemical and biological defense capabilities noted in this report, we recommend that the Secretary of Defense reevaluate the priority and emphasis given to this area throughout DOD. We also recommend that the Secretary, in his next annual report to Congress on NBC Warfare Defense, address (1) proposed solutions to the deficiencies identified in this report and (2) the impact that shifting additional resources to this area might have on other military priorities.

If the Secretary's reevaluation of the priority and emphasis given chemical and biological defense determines that more emphasis is needed, and if efforts by the Joint Service Materiel and Joint Service Integration Groups prove less effective than desired, the Secretary should consider elevating the single office for program oversight to the assistant secretary level in DOD rather than leaving it in its present position as part of the Office of the Assistant Secretary for Atomic Energy. The Secretary should also consider adopting an increased single manager concept for the execution of the chemical and biological program. This would provide a single manager with more authority, responsibility, and accountability for directing program management and acquisition for all the services.

We further recommend that the Secretary of Defense take the following specific actions designed to improve the effectiveness of existing activities:

- Direct FORSCOM to reevaluate current chemical defense equipment stock requirements for early deploying active and reserve units to determine the minimal amounts required to be on hand to meet deployment requirements and to determine any additional storage facility requirements. If chemical defense equipment stock requirements are retained, we recommend that FORSCOM take the actions necessary to see that early deploying units can and do maintain these stocks.
- Review some services' practice of funding the purchase of this equipment through Operation and Maintenance, rather than Procurement, funds. This review is necessary because Operation and Maintenance funds intended for chemical and biological defense equipment and training are too easily and frequently diverted to other purposes, and the uses of these funds are

not well recorded. A consistent DOD system for funding these activities and recording the amount of funds spent on chemical and biological defense would greatly improve oversight of the resources and emphasis directed to this area. We recommend that DOD also consider at least temporarily earmarking Operation and Maintenance funds to relieve existing shortages of this equipment if current funding practices for purchasing this equipment are retained.

- Consider modifying SORTS to require active Army divisions to complete and submit SORTS division summaries for chemical and biological reporting categories, and implementing changes that would require overall unit readiness assessments to be more directly affected by their chemical and biological readiness status. More emphasis should be placed on accurately inventorying and reporting unit stocks of critical chemical and biological defense equipment through SORTS and other monitoring and reporting systems. SORTS reporting requirements should also be modified to more accurately reflect shortcomings in units' ability to meet existing chemical and biological training standards.
- Determine and direct the implementation of an effective and appropriate immunization program for biological warfare defense that is consistent with existing DOD immunization policy.
- Direct that DOD medical courses of instruction regarding chemical and biological warfare treatment techniques, such as the Management of Chemical and Biological Casualties Course, be directed toward those personnel occupying positions in medical units most likely to have need of this training and that medical units assigned such personnel keep adequate records to determine whether the appropriate number and types of their personnel have attended such courses.
- Direct the Secretary of the Army to ensure that tactical unit training addresses casualty decontamination and that the current confusion regarding responsibility for performing casualty decontamination is corrected.
- Direct the Secretary of the Army and the Commandant of the Marine Corps to ensure that all combat training centers routinely emphasize and include chemical and biological training, and that this training is conducted in a realistic manner. Further, we recommend that the Secretary and the Commandant direct units attending these centers to be more effectively evaluated on their ability to meet existing chemical and biological training standards.
- Direct the CINCs to routinely include joint chemical and biological training tasks in exercises conducted under the CJCS exercise program and evaluate the ability of joint forces to perform chemical and biological tasks.

Further, we recommend that the Secretary direct the CINCs to report annually on the results of this training.

Agency Comments

DOD generally concurred with the report findings, and acknowledged that a relatively low emphasis has been placed on chemical and biological defense in the past. DOD also concurred with 9 of the10 report recommendations. In commenting on this report, DOD stated it has recently increased the emphasis and funding given to chemical and biological defense and has begun a number of initiatives that are expected to address many of the problems we identified. DOD's full comments and our evaluation are shown in appendix VI.

A discussion of our scope and methodology is in appendix V. We conducted our review from October 1994 to December 1995 in accordance with generally accepted government auditing standards.

We are sending copies of this report to the Chairmen and Ranking Minority Members of the Senate Committee on Armed Services, the House Committee on National Security, and the Senate and House Committees on Appropriations; the Secretaries of Defense and the Army; the Commandant of the Marine Corps; and the Chairman, Joint Chiefs of Staff. Copies will also be made available to others upon request.

Please contact me at (202) 512-5140 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix VII.

Mark E. Gebicke

Mark E. Gebicke
Director, Military Operations
and Capabilities Issues

Contents

Abbreviations

CJCS	Chairman of the Joint Chiefs of Staff
CINC	commanders in chief
DOD	Department of Defense
FDA	Food and Drug Administration
FORSCOM	U.S. Forces Command
IND	Investigational New Drug
NBC	nuclear, biological, and chemical
ORE	operational readiness evaluation
SORTS	Status of Resources and Training System

Recurring Weaknesses in Army Chemical and Biological Capabilities, Fiscal Years 1994-95

Task	2d Army[a] (percentage of units inadequately trained)[b]	5th Army[c] (percentage of units inadequately trained)	Found in Gulf War
Donning protective masks			Yes
Active	39	50	
National Guard	57	88	
U.S. Army Reserve	84	81	
Decontamination			Yes
Active	33	10	
National Guard	61	60	
U.S. Army Reserve	48	75	
School-trained NBC officer			Not applicable
Active	5	17	
National Guard	31	34	
U.S. Army Reserve	35	19	
Preparing for a chemical attack			Yes
Active	67	23	
National Guard	77	50	
U.S. Army Reserve	50	60	
Responding to a chemical attack			Yes
Active	63	15	
National Guard	53	67	
U.S. Army Reserve	56	60	
Integrating chemical and biological tasks into training			N/A
Active	26	0	
National Guard	31	35	
U.S. Army Reserve	29	40	

(Table notes on next page)

[a]In June 1995, the 1st Army, located at Fort Meade, Maryland, and the 2d Army, located at Fort Gillem, Georgia, were consolidated. The new consolidated unit is called the 1st Army. Our review of operational readiness evaluation (ORE) covered the 138 evaluations conducted by the former 2d Army in fiscal year 1994 and the first half of fiscal year 1995. Second Army OREs included 138 units—19 Active, 31 Army Reserve, and 88 National Guard.

[b]Based on the results of our ORE analysis, we considered units to be inadequately trained if they were classified by the Army as being either untrained or partially trained.

[c]In May 1995, the 6th Army located at the Presidio of San Francisco, California, and the 5th Army located at Fort Sam Houston, Texas, were consolidated as the new 5th Army. Our review of OREs covered the 83 evaluations conducted by the former 5th Army in fiscal year 1994 and the first half of fiscal year 1995. Fifth Army OREs included 83 units—18 Active, 28 Army Reserve, and 37 National Guard.

Sources: Operational Readiness Evaluations, 2d and 5th Continental U.S. Armies, and Chemical Lessons Learned, Documents From Operations Desert Shield/Storm, August 1990 through July 1991.

Army Chemical and Biological Trendline Data From Combat Training Centers, Fiscal Years 1989-90

Task measured	Percent untrained	Found in Gulf War
Battle Management		Yes
Use of chemical units/officers	94	
Casualty evaluation	92	
Threat analysis	60	
Advising commanders	75	
Intelligence preparation of battlefield	60	
Contamination avoidance		Yes
Employment of chemical alarms	90	
Use of detection kits	86	
Implementation of warning system	73	
Decontamination		Yes
Planning	45	
Execution	80	
Protection		Yes
Distribution of protective gear	50	
Donning appropriate gear	73	
Unmasking procedures	100	
Administering first aid	83	

Note: Data collected from 31 rotations of infantry, airborne, special operations, armored cavalry, mechanized and motorized infantry, air assault, and heavy and light forces from October 1988 to October 1990.

Source: Nuclear, biological, and chemical (NBC) Trendline Study from the Command Training Centers Final Report, U.S. Army Chemical School, March 1991, and Chemical Lessons Learned Documents from Operations Desert Shield/Storm, dated August 1990 through July 1991.

CJCS Exercises That Include Joint Training Tasks, Fiscal Years 1995-96

	Number of joint exercises		Exercises that include chemical/biological tasks	
Command	**1995**	**1996**	**1995**	**1996**
CENTCOM	88	64	2	2
EUCOM	57	69	7	6
PACOM	[a]	31	[a]	13
USACOM	9	6	6	5
Total	**154**	**170**	**15**	**26**

Note: CENTCOM, Central Command; EUCOM, European Command; PACOM, Pacific Command; USACOM, Atlantic Command.

[a]PACOM did not provide information for fiscal year 1995.

Source: U.S. Central, Atlantic, European, and Pacific commands.

Extent to Which 23 Joint Chemical/ Biological Tasks Are Included in Planned CJCS Exercises, Fiscal Year 1996

Command	Total planned exercises with chemical/ biological tasks	23 tasks	15-22 tasks	10-14 tasks	5-9 tasks	1-4 tasks
CENTCOM	2	0	1	1	0	0
EUCOM[a]	6	[a]	[a]	[a]	[a]	[a]
PACOM	13	0	0	0	1	12
USACOM	5	0	0	0	2	3

[a]EUCOM did not provide information on specific chemical and biological tasks done in its joint exercises.

Objectives, Scope, and Methodology

The Chairman and Ranking Minority Member, Subcommittee on Military Readiness, House Committee on National Security, requested that we provide a current assessment of the ability of early deploying U.S. ground forces to survive and operate in a chemically or biologically contaminated environment. Our objectives were to determine (1) DOD's actions to address chemical and biological warfare defense problems identified during the Gulf War and (2) the current preparedness of these forces to operate in a contaminated environment.

To determine the Department of Defense's (DOD) actions to correct the problems identified in the Gulf War, we reviewed DOD's Nuclear/Biological/Chemical (NBC) Warfare Defense annual reports submitted in 1994 and 1995 to Congress, lessons-learned documents, and other studies prepared by the Joint Chiefs of Staff, the Army, and the Marine Corps. We performed a similar analysis of problems identified in routine training exercises conducted under the Chairman, Joint Chiefs of Staff Exercise Program and at the Army's combat training centers—the National Training Center, located at Fort Irwin, California; the Joint Readiness Training Center, located at Fort Polk, Louisiana; the Combat Maneuver Training Center, located at Hohenfels, Germany; and the Marine Corps Air Ground Combat Center at 29 Palms, California. We also analyzed operational readiness inspections and evaluations and other Army and Marine Corps documents that assessed the results of home station training exercises.

To determine the preparedness of U.S. ground forces to operate in a chemical or biological environment, we focused on three areas: the availability of critical chemical and biological defense equipment, such as protective suits, masks, and alarms; the adequacy of chemical and biological training, including the extent to which tasks are conducted in joint and service training; and the availability of medical countermeasures to prevent and treat chemical and biological casualties, including supplies of critical vaccines and medical procedures to decontaminate and evacuate casualties.

Regarding equipment availability at the units visited, we compared equipment on hand with that required by Army and Marine Corps regulations. To determine training adequacy, we analyzed Army, Marine Corps, and Joint Staff training guidance specifying chemical and biological tasks to be done as well as after-action and lessons-learned reports to identify any weaknesses. We also analyzed the training exercises conducted under the Chairman, Joint Chiefs of Staff Exercise Program to

determine the extent that joint exercises include chemical and biological defense training. To assess the adequacy of medical countermeasures, we interviewed DOD officials and analyzed lessons-learned reports from the Gulf War to determine what problems had occurred. We then assessed medical unit equipment availability and training, the training provided to military physicians for the treatment and management of chemical and biological casualties, and the adequacy of biological agent vaccine stocks and policies and procedures for their use.

We also assessed the efforts by DOD, the Joint Staff, and CINCs to monitor chemical and biological readiness. We interviewed key officials, examined guidance and reporting requirements, and analyzed reports to determine the extent that chemical and biological matters are included.

We met with key DOD, Joint Staff, and service officials to discuss chemical and biological problems and the efforts to correct them; as well as readiness issues, including the emphasis placed on chemical and biological matters and other issues. At the DOD level, we contacted officials in the offices of the Assistant Secretary of Defense (Atomic Energy) (Chemical and Biological Matters); the Armed Forces Medical Intelligence Center, Fort Detrick, Maryland; and the Joint Program Office for Biological Defense. At the Joint Staff level, we met with officials in the offices of the Director for Strategic Plans and Policy (J-5), Weapons Technology Control Division, and the Director for Operational Plans and Interoperability (J-7), Joint Exercise and Training Division. At the commander in chief (CINC) level, we contacted officials at the U.S. Atlantic, Central, European, and Pacific Commands. At the Army, we held discussions and reviewed documents at U.S. Army Forces Command, Fort McPherson, Georgia; the U.S. Army Reserve Command, Atlanta, Georgia; the Office of the Army Surgeon General, Falls Church, Virginia; the Army Chemical School, Fort McClellan, Alabama; the Army Medical Command and the Army Medical Department Center and School, Fort Sam Houston, Texas; the Chemical and Biological Defense Command, Aberdeen, Maryland; the U.S. Army Medical Research Institute of Infectious Diseases, Fort Detrick, Maryland; Walter Reed Army Medical Center, Washington, D.C.; and the U.S. Army Medical Research and Materiel Command, Fort Detrick, Maryland.

We interviewed officials and reviewed documents at the Army's III Corps Headquarters, Fort Hood, Texas; the XVIII Airborne Corps Headquarters, Fort Bragg, North Carolina; and the Marine Corps' Combat Development and Combat Systems Development Commands, Quantico, Virginia.

We visited four of the 5-1/3 active Army divisions composing the crisis response force as well as the 2d Armored Division, Fort Hood, Texas, and the 25th Light Infantry Division, Schofield Barracks, Hawaii.

We visited the 2d U.S. Army (now 1st U.S. Army) headquarters, Fort Gillem, Georgia; the 5th U.S. Army headquarters, Fort Sam Houston, Texas; the 90th U.S. Army Reserve Command, San Antonio, Texas; the 98th U.S. Army Reserve Support Command, Little Rock, Arkansas; and the 143d Transportation Command, Orlando, Florida. We also visited a chemical company, a chemical detachment, a chemical brigade headquarters, a signal company, an engineer group, and a transportation detachment from the U.S. Army Reserves that, at the time of our review, were designated for deployment in less than 30 days from mobilization.

We visited the following Marine Corps Units:

- II Marine Expeditionary Force, Camp Lejeune, North Carolina;
- II Marine Division, Camp Lejeune, North Carolina;
- II Marine Force Service Support Group, Camp Lejeune, North Carolina; and
- II Marine Aircraft Wing, Cherry Point, North Carolina.

We conducted our work from October 1994 to December 1995 in accordance with generally accepted government auditing standards.

Comments From the Secretary of Defense

ASSISTANT TO THE SECRETARY OF DEFENSE
3050 DEFENSE PENTAGON
WASHINGTON, DC 20301-3050

MAR 20 1996

ATOMIC ENERGY

Mr. Mark E. Gebicke
Director, Military Operations and Capabilities Issues
National Security and International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Gebicke:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) Draft Report, "CHEMICAL AND BIOLOGICAL DEFENSE: Emphasis Remains Insufficient To Resolve Continuing Problems," dated February 29, 1996 (GAO Code 703082) OSD Case 1099.

While the DoD generally concurs with the draft report, there are underway a number of initiatives as outlined in our responses that will address many of the problems identified.

In addition, over the past two years, the Chemical and Biological Defense (CBD) program has received increased emphasis and funding within the DoD. The DoD is continuing to work diligently to integrate and coordinate all Services' CBD requirements. The current CBD program is also undergoing a detailed program assessment as part of a review of the entire Counterproliferation program. Results of the assessment are expected within the next several months, and will serve to validate existing CBD programs and identify additional program requirements.

The DoD's detailed response to the GAO's recommendations are provided in the enclosure. Other suggestions of a technical nature to improve the accuracy and clarity of the report were provided to the GAO staff separately. The Department appreciates the opportunity to comment on the draft report.

Sincerely,

Harold P. Smith, Jr.

Enclosure

**GAO DRAFT REPORT DATED FEBRUARY 29, 1996
(GAO CODE 703082) OSD CODE 1099**

"CHEMICAL AND BIOLOGICAL DEFENSE: EMPHASIS REMAINS INSUFFICIENT TO RESOLVE CONTINUING PROBLEMS"

DEPARTMENT OF DEFENSE COMMENTS ON THE GAO RECOMMENDATIONS

Now on p. 19.

RECOMMENDATION 1: In view of the increasing chemical and biological warfare threat and the continuing weaknesses in U.S. chemical and biological defense capabilities noted in the GAO Report, the GAO recommended that the Secretary of Defense reevaluate the priority and emphasis given to this area throughout the Department of Defense. (p. 20/GAO Draft Report)

DOD RESPONSE: Concur. The Department of Defense (DoD) Chemical and Biological Defense (CBD) Program is a high priority program of this administration. Over the past two years, the CBD program has received increased emphasis and funding. In addition, the Fiscal Year 1994 National Defense Authorization Act has energized and provided direction for significant oversight of the CBD program.

As with all DoD programs, the DoD is continuously analyzing and evaluating threats, mission scenarios, force structures, training requirements, and Research, Development and Acquisition (RDA) programs. The current CBD program is undergoing a detailed program assessment as part of a broader review of the Counterproliferation program. The results of this analysis may impact priority and funding levels. The detailed program assessment is scheduled to be completed on June 30, 1996.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense, in his next annual report to the Congress on Nuclear, Biological and Chemical (NBC) Warfare Defense, address (1) proposed solutions to the deficiencies identified in this report and (2) the impact that shifting additional resources to this area might have on other military priorities. The GAO suggested that if the Secretary's reevaluation of the priority and emphasis given chemical and biological defense determines that more emphasis is needed, and efforts by the Joint Service Materiel and Joint Service Integration Groups prove less effective than desired, the Secretary may wish to consider elevating the single office for program oversight to the assistant secretary level in the DoD, rather than leaving it in its present position as part

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of the Office of the Assistant [to the] Secretary [of Defense] for Atomic Energy. The GAO further suggested that the Secretary may also wish to consider adopting a single manager concept for the execution of the chemical and biological program. This would provide a single manager with the authority, responsibility, and accountability for directing program management and acquisition for all the services. (p. 20/GAO Draft Report)

DOD RESPONSE: Concur. The previous three Annual Reports to Congress on the CBD Program have highlighted proposed solutions to on-going deficiencies. These on-going RDA solutions are highlighted within our CBD Mission Area Modernization Strategy. In addition, proposed solutions to deficiencies are also identified in the Logistics and Training chapters of the Annual Report to Congress.

Shifting funds into the CBD area should not have a significant impact on other funding areas because the CB funding area is relatively small (less than 1% of the overall budget). However, budget cuts to the CBD area can have major impacts on the CBD program execution. An important point to emphasize here is that Congress recognized that putting additional funds into separate DoD and other department and Agency lines led to duplication and overlap of effort and that any funding increases for CB defense should be put into the single DoD line to ensure a coordinated and integrated program. Putting additional funding into diverse and uncoordinated efforts could lead to a resurgence of this problem.

The 103rd Congress recognized the importance of the CBD program, and changed the name of the Assistant to the Secretary of Defense (Atomic Energy) (ATSD(AE)) to Assistant to the Secretary of Defense (Nuclear and Chemical and Biological Defense Programs) (ATSD(NCB)).

See comment 1.

Our current management structure already focuses around a single manager. In accordance with Section 1701 of the Fiscal Year 1994 National Defense Authorization Act, that individual is the ATSD(NCB).

We also concur with the GAO recommendation that if a reevaluation of the priority and emphasis given chemical and biological defense determines that more emphasis is needed, the Secretary may wish to consider elevating the single office for program oversight to the assistant secretary level.

With continued Congressional support, adequate resources to provide oversight of the program and to implement on-going modernization strategies, the program will continue to improve.

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RECOMMENDATION 3: The GAO further recommended that the Secretary of Defense take the following specific actions designed to improve the effectiveness of existing activities. First, the GAO recommended that the Secretary direct U.S. Army Forces Command (FORSCOM) to reevaluate current chemical defense equipment stocking requirements for early deploying active and reserve units to determine the minimal amounts required to be on hand to meet deployment requirements and to determine any additional storage facility requirements. If chemical defense equipment stocking requirements are retained, FORSCOM needs to take the actions necessary to see that early deploying units can and do maintain these stocks. (p. 20/GAO Draft Report)

DOD RESPONSE: Concur. FORSCOM is currently in the process of revising its policy concerning stocking and storing contingency Chemical Defense Equipment.

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RECOMMENDATION 4: Second, the GAO recommended that the Secretary of Defense review the practice of some Services' funding the purchase of this equipment through Operation and Maintenance funding, while others use Procurement funds. The GAO stated that this review needs to be performed because Operation and Maintenance funds intended for chemical and biological defense equipment and training are too easily and frequently diverted to other purposes, and the uses of these funds are not well recorded. The GAO concluded that a consistent DoD system for funding these activities and recording the amount of funds spent on chemical and biological defense would greatly improve oversight of the resources and emphasis directed to this area. The GAO further recommended that the DoD also consider at least temporarily earmarking Operation and Maintenance funds to relieve existing shortages of this equipment if current funding practices for purchasing this equipment are retained. (p. 20-21/GAO Draft Report)

DOD RESPONSE: Concur. The DoD is reviewing the Uniformed Equipment Acquisition Policy as directed by the Under Secretary of Defense (Acquisition and Technology)(USD(A&T)) to identify the types of CBD equipment that should be centrally procured through the CBD program and the funding lines that need to transfer between the CBD program and Service Accounts. Recommendations from the Equipment Acquisition Integrated Product Team will be forwarded for consideration in April 1996.

RECOMMENDATION 5: Third, the GAO recommended that the Secretary of Defense consider modifying the Status of Resources and

Training System (SORTS) to require active Army divisions to complete and submit SORTS division summaries for chemical and biological reporting categories, and implementing changes that would require overall unit readiness assessments to be more directly affected by their chemical and biological readiness status. The GAO stated that more emphasis should be placed on accurately inventorying and reporting unit stocks of critical chemical and biological defense equipment through SORTS and other monitoring and reporting systems. In addition, the GAO recommended that SORTS reporting requirements should also be modified to more accurately reflect shortcomings in unit ability to meet existing chemical and biological training standards. (p. 21/GAO Draft Report)

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DOD RESPONSE: Nonconcur. SORTS is not intended to function as a detailed management tool to report on all conceivable variables. Rather, SORTS does provides a broad band of information on selected unit status indicators and includes the commander's assessment of the unit's ability to execute its full wartime mission. Units assessed routinely report their equipment on hand and training status for operations in a chemical and biological environment. Commanders combine this information with other factors, including wartime mission to provide an overall assessment of a unit's ability to go to war.

See comment 2.

RECOMMENDATION 6: Fourth, the GAO recommended that the Secretary of Defense determine and direct the implementation of an effective and appropriate immunization program for biological warfare defense that is consistent with existing DoD immunization policy. (p. 21/GAO Draft Report)

Now on p. 20.

DOD RESPONSE: Concur. DoD is reviewing the existing DoD Immunization Policy (DoD Directive 6205.3, Dated November 26, 1993). The Army, as executive agent, is developing alternative vaccine immunization implementation plans to be coordinated with the Joint Staff and the Services leading to a decision by the Deputy Secretary Defense. This process is expected to be completed within the next several months. Funding for procurement of the vaccine stockpile has been identified. At this time, a Request For Proposal is ready for release to procure the vaccine.

RECOMMENDATION 7: Fifth, the GAO recommended that the Secretary of Defense direct that DoD medical courses of instruction regarding chemical and biological warfare treatment techniques, such as the Management of Chemical and Biological Casualties Course, be directed toward those personnel occupying positions in medical units most likely to have need of this training, and that

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medical units assigned such personnel keep adequate records to determine whether the appropriate number and types of their personnel have attended such courses. (p. 21/GAO Draft Report)

DOD RESPONSE: Concur. The DoD agrees that greater should be placed on medically relevant NBC training. The DoD is considering increased medical NBC training as it implements a new DoD Instruction, "Military Medical Readiness Skills Training." The DoD is also considering additional NBC physician training requirements in part of DoDD 6025.13, "Clinical Quality Management Program (CQMP) in the Military Health Services," dated July 20, 1995.

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RECOMMENDATION 8: Sixth, the GAO recommended that the Secretary of Defense direct the Secretary of the Army to ensure that tactical unit training addresses casualty decontamination and that the current confusion regarding responsibility for performing casualty decontamination is corrected. (p. 21/GAO Draft Report)

See comment 3.

DOD RESPONSE: Concur. Current Army doctrinal manuals provide specific responses for patient decontamination for all units. These manuals form the basis for training exercises to reinforce these responsibilities. Army doctrine in Field Manual 3-5, NBC Decontamination, specifically assigns responsibility for patient decontamination to a nonmedical team from the supported unit. This team would operate under the supervision of medical personnel to ensure that no further injury is caused to the patient. While current Army doctrinal manuals are clear on this issue, Joint Doctrine across the Services does not yet exist. The DoD is considering an overall departmental policy on this issue.

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RECOMMENDATION 9: Seventh, the GAO recommended that the Secretary of Defense direct the Secretary of the Army and the Commandant of the Marine Corps to ensure that all combat training centers routinely emphasize and include chemical and biological training, and that this training is conducted in a realistic manner. The GAO further recommended that the Secretary and the Commandant should direct that units attending these centers be more effectively evaluated on their ability to meet existing chemical and biological training standards.
(p. 21/GAO Draft Report)

DOD RESPONSE: Concur. The Army and Marine Corps training guidance documents require Commanders to ensure individuals and units are trained to defend and survive in a chemical and biological environment. The Navy and Air Force have similar

See comment 4.

requirements. For example, the FORSCOM Commander's NBC Defense Training Guidance, dated Sept 29, 1995, requires that commanders ensure that units are fully trained to sustain operations and defend against battlefield NBC hazards. All units are required to: (1) integrate NBC individual and collective tasks into all aspects of training; (2) use the Battle Command Training Program to enhance key leader and staff NBC defense training; and (3) fully demonstrate unit proficiency in realistic battlefield NBC environments at the combat training centers. The DoD, with the Joint Staff and the Services, will review evaluation standards for the training centers, to determine their efficacy.

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RECOMMENDATION 10: Finally, the GAO recommended that the Secretary of Defense direct the Commanders-in-Chiefs (CINCs) to routinely include joint chemical and biological training tasks in exercises conducted under the Joint Chiefs of Staff (JCS) Exercise Program and evaluate the ability of joint forces to perform chemical and biological tasks. The GAO further recommended that the Secretary should direct the CINCs to report annually on the results of this training. (p. 21/GAO Draft Report)

DOD RESPONSE: Concur. The DoD agrees with the need to Improve CB training in joint exercises. This issue was commended to the CINCs by the Chairman of the JCS (CJCS) as a priority training requirement within the December 1995 Joint Training Master Plan (CJCSI 3500.02). As a result, combatant commands are creating FY 97-99 joint training plans to add the CJCS commended training initiatives to their requirements. This requirement is already being evaluated by the joint exercise and training community.

The following are GAO's comments on DOD's letter dated March 20, 1996.

GAO Comments

1. Our report acknowledges that a single office within DOD currently has responsibility for chemical and biological program oversight and execution. However, as we noted in our report, many aspects of joint military service planning of research, development, acquisition, and logistics support for chemical and biological activities are dependent on the effectiveness of the committee-like Joint Service Integration and Joint Service Materiel Groups. The effectiveness of these groups in resolving interservice chemical and biological issues remains to be seen, and the Joint Service Integration Group was continuing to have start-up staffing problems at the time of our review. Some DOD officials have expressed concern regarding the ability of these groups to obtain sufficient support and emphasis from the individual services to be effective. We believe more of a single manager approach to this planning should be considered if these groups are unable to effectively address current problems and develop timely solutions. We have slightly modified our recommendation to clarify our position on this point.

2. We agree that the Status of Resources and Training System (SORTS) is not intended to function as a detailed management tool. However, the current system leaves significant opportunity for broadly inaccurate reporting of unit chemical and biological preparedness status. For example, although 3 of the 5-1/3 Army divisions composing the crisis response force had 50 percent or less of the protective clothing required by regulations for chemical and biological defense, these shortages were discernable through SORTS for only one of these divisions. This type of problem was evident during the Persian Gulf conflict, as after-action reports and other analyses revealed that units reporting 90 to 95 percent of their equipment on hand through SORTS actually had far less serviceable equipment for a variety of reasons, thereby causing logisticians and transporters to make extraordinary post-mobilization and post-deployment efforts to fill requisitions for unit shortages.

Furthermore, during our review, at least one early deploying division was able to report C-1 for individual protective equipment status (90 percent or more of equipment on hand) although less than 50 percent of the required protective clothing and other items were actually available (C-4 status). This occurred because Army regulations allow units to forego reporting on equipment stored in facilities not specifically controlled by the unit. In this case, the division's chemical defense equipment was stored in a

warehouse controlled by corps headquarters, and reporting these shortages through SORTS was therefore not required, even though the corps headquarters and the division were physically located on the same installation. In this case, the level of stockage was not only inadequate for the division, but for other early deploying units within the corps as well. Also, leaving SORTS reporting mandatory for individual units, but optional for divisions, not only complicates the process but also makes review by higher commands such as U.S. Forces Command (FORSCOM) much more difficult.

Finally, DOD's annual reports to Congress acknowledged continuing problems regarding the accountability and management of NBC defense item inventories. While we concur that SORTS is not an appropriate tool for detailed management, we believe the assessment it provides, particularly regarding unit inventories of critical chemical and biological defense equipment, needs to be reasonably accurate in order to provide a meaningful readiness assessment. As long as units are required to be capable of defending themselves and operating in a contaminated environment, we believe that a readiness evaluation system that permits an overall unit readiness rating of C-1 while chemical and biological equipment readiness is rated C-4 could easily provide misleading information about that unit's actual combat readiness. Also, requiring at least a moderate level of chemical and biological readiness in order to achieve a high overall readiness rating would do much to emphasize chemical and biological defense, and thus address some of the disparity that often occurs between the level of emphasis placed on chemical and biological defense by DOD policy and guidance and that actually being applied at unit level (see comment 4). We are therefore retaining this recommendation.

3.There is no question that Army doctrine and manuals are clear about who has responsibility for patient decontamination. However, both medical and tactical units we visited that were involved in implementing these tasks were often unaware of the doctrine and, consequently, usually had not either planned or trained to perform these functions.

4. We concur that military service training documents and standards require commanders to ensure that units and individuals are trained to defend and survive in a contaminated environment. However, there appears to be a difference between the policy and guidance established and the extent to which it has been effectively applied. For example, while the last two FORSCOM commanders have issued NBC defense training

guidance requiring commanders to ensure that units are fully trained to sustain operations and defend against battlefield NBC hazards, the various DOD readiness and evaluation mechanisms we reviewed continue to indicate that many units are in fact not trained to DOD standards for chemical and biological defense. Our report also shows that Army unit commanders have not met FORSCOM requirements for unit on-hand stocks for critical NBC equipment, and that FORSCOM has not provided either the funds or the supervisory oversight needed to ensure compliance.

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DOCUMENT 3

Protection Factor Testing of the Responder Suit

AD-A306 168

January 1996

U.S. Army Edgewood Research, Development and Engineering Center Aberdeen Proving Ground, MD

EDGEWOOD
RESEARCH DEVELOPMENT & ENGINEERING CENTER
U.S. ARMY CHEMICAL AND BIOLOGICAL DEFENSE COMMAND

ERDEC-TR-312

PROTECTION FACTOR TESTING OF THE RESPONDER SUIT

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January 1996

Aberdeen Proving Ground, MD 21010-5423

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1996 January	Final, 95 Jun - 95 Nov

4. TITLE AND SUBTITLE
Protection Factor Testing of the Responder Suit

5. FUNDING NUMBERS
None

6. AUTHOR(S)
Arca, Victor J.; Ramos, Gabriel A.; Reeves, Dennis W.; Blewett, William K.; Fatkin, David P.; and Cannon, Brenda D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
DIR, ERDEC, ATTN: SCBRD-RTB, APG, MD 21010-5423

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDEC-TR-312

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
CDR, CBDCOM, ATTN: CSEPP Team, APG, MD 21010-5423

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Testing was conducted to measure the protective capability of a commercial chemical-protective suit (Responder™) against toxic vapors or aerosols. The standard U.S. Army Battle Dress Overgarment (BDO) was also included in the test. Both the Responder™ and the BDO were worn with an industrial powered respirator and an Army-designed hood. The testing was conducted at the U.S. Army Edgewood Research, Development and Engineering Center on 19-30 Jun 95 and consisted of nine trials, each involving up to four test subjects. In each trial, the test subjects wore the Responder™ suit for 30 min while performing a series of exercises in a chamber filled with a mustard simulant vapor, methyl salicylate, at a concentration of 50 mg/m^3. Vapor concentrations were measured at several locations beneath the suit with passive sampling devices containing the solid adsorbent Tenax. Results show that the Responder™ suit provides protection equivalent to the BDO when worn with the hood tucked into the collar to direct filtered air into the suit. With wrists taped and with either ankles taped or integral foot covers, the Responder™ provided protection greater than the BDO.

14. SUBJECT TERMS

Tenax	Passive sampling	BDO	CSEPP
PAPR mask	Methyl salicylate	NBC	JSLIST
Responder™	Chemical protection	CDRA	Protection factor

15. NUMBER OF PAGES
69

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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EXECUTIVE SUMMARY

The purpose of this work was to determine the capability of a commercial chemical-protective suit to protect against toxic vapors or aerosols. This was accomplished by conducting man-in-simulant tests (MIST) at the U.S. Army Edgewood Research Development and Engineering Center (ERDEC), Aberdeen Proving Ground, MD. The testing was conducted under the auspices of the Chemical Stockpile Emergency Preparedness Program (CSEPP).

The commercial suit tested was the Kappler Life-Guard Responder™ splash suit. As a candidate for use by first responders in the event of a chemical incident at the Tooele Army Depot chemical stockpile storage site, it was tested per direct request by the State of Utah. The material of this suit had previously passed chemical agent exposure tests. The standard U.S. Army Battle Dress Overgarment (BDO) was included in the test as well.

Both suits were tested as part of an ensemble consisting of a Mine Safety Appliances OptimAir 6A powered respirator, an Army-designed Powered Air-Purifying Respirator Hood, standard U.S. Army 25-mil butyl rubber gloves, and standard U.S. Army Green Vinyl Overshoes.

Variations in the configuration of the Responder were tested: sleeves taped at the wrists, legs taped at the ankles, and integral foot covers versus no foot covers. In each configuration, the hood of the respirator was tucked into the suit to direct filtered air into the suit.

The testing consisted of nine trials, each involving up to four test subjects. The Responder™ was worn 20 times and the BDO nine times in the trials. Sixteen volunteer test subjects from ERDEC and the Tooele Chemical Demilitarization Facility (TOCDF) participated as test subjects. In each trial, they wore the chemical protective ensemble for 30 minutes in a chamber filled with vapor of a mustard simulant, methyl salicylate, at a concentration of 50 mg/m^3. The subjects performed a series of movements and exercises during this 30-minute period. Vapor concentrations were measured in several locations beneath the suit with passive sampling devices containing the solid sorbent Tenax.

Results show that the Responder™ suit provides the highest level of protection when worn with the hood tucked into the suit to direct filtered air into the suit, with wrists taped, and with either ankles taped or integral foot covers.

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PREFACE

The work described in this report was funded by the Chemical Stockpile Emergency Preparedness Program (CSEPP). This work was started in June 1995 and completed in November 1995.

The use of trade or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This report may not be cited for purposes of advertisement.

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Acknowledgments

The authors gratefully acknowledge the technical contributions of Dr. Paul Fedele of the Research and Technology Directorate, U.S. Army Edgewood Research, Development and Engineering Center, who reviewed the passive sampler data and recommended an accounting technique for simulant background levels in the analysis.

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PROTECTION FACTOR TESTING OF THE RESPONDER SUIT

1. INTRODUCTION

This report describes chemical vapor challenge testing of a protective ensemble that has been proposed for use by fire-fighters, policemen, and other off-site civilian emergency personnel in the event of an accidental release of toxic agents from chemical weapons demilitarization and storage facilities.

The Life-Guard Responder™ was selected as a candidate for this application after a study by the U.S. Army Chemical Demilitarization and Remediation Activity (CDRA) identified it as one of two commercial suits capable of protecting against all the stockpiled chemical agents.[1] This ensemble, shown in Figure 1, has five components:

- A Life-Guard Responder™ splash suit, manufactured by Kappler USA, Inc.
- A Mine Safety Appliances OptimAir 6A powered respirator, model 800375
- An Army-designed Powered Air-Purifying Respirator Hood
- Standard U.S. Army 25-mil butyl rubber gloves
- Standard U.S. Army Green Vinyl Overshoes (GVOs).

The OptimAir 6A powered respirator, which provides a filtered airflow of 6 ft^3/minute, was employed with a NIOSH certified filter (Approval no. TC-23C-1263) for protection against organic vapors, pesticides, dusts, fumes, mists, and radionuclides. The respirator and Army-designed hood are shown in Figure 2.

The testing of this ensemble was conducted for the Chemical Stockpile Emergency Preparedness Program (CSEPP) by the Ventilation Kinetics Team of the U.S. Army Edgewood Research, Development and Engineering Center (ERDEC).

2. OBJECTIVES

- To measure the level of protection provided by the ensemble against chemical vapors.

- To determine the degree to which applying tape to the wrist and ankle closures of the suit affects the level of protection.

- To identify and recommend potential improvements to the configuration of the ensemble.

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[1]Personal Protective Equipment (PPE) Alternatives for Non-Stockpile Operations, Test Report, Final, December 1994. U.S. Army Chemical Demilitarization and Remediation Activity.

Figure 1. The Life-Guard Responder Suit with Respirator, Hood, Gloves, and Overshoes.

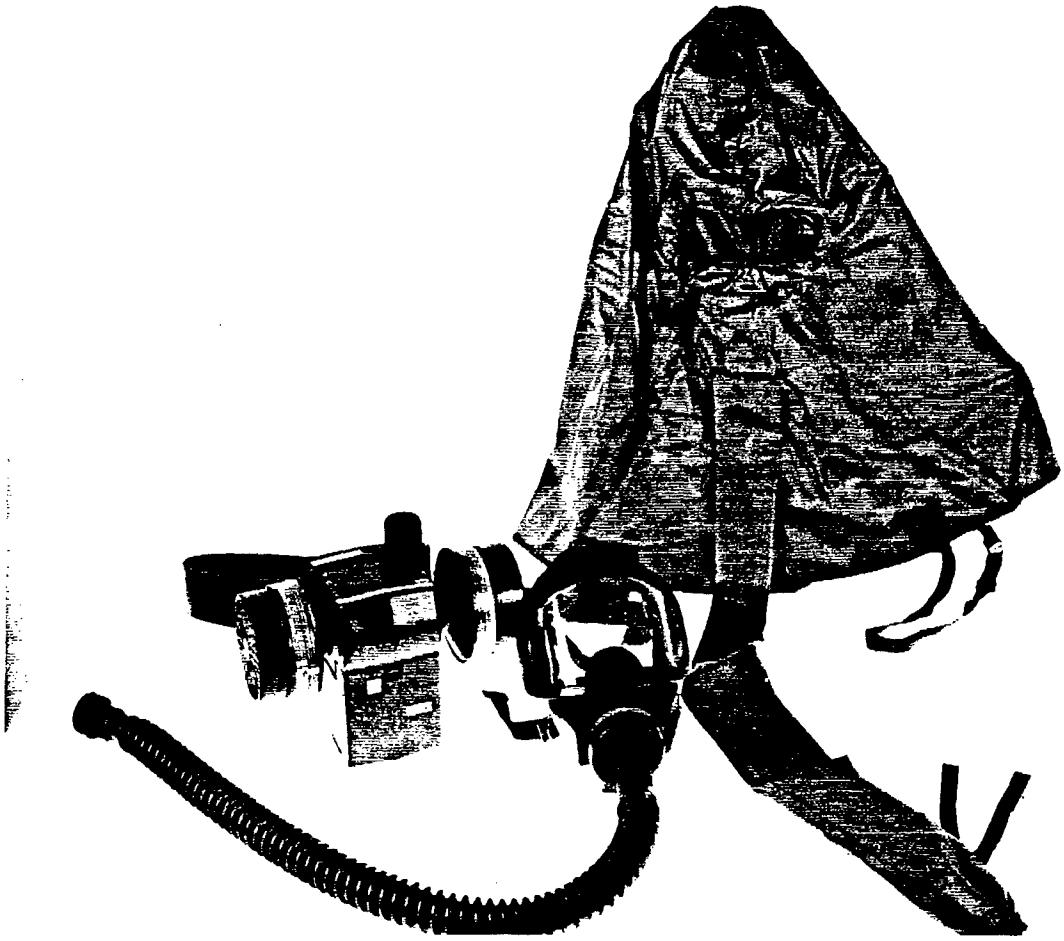

Figure 2. The PAPR Mask, Hood, and Filter Blower Assembly.

3. SCOPE

This testing was conducted according to guidelines set forth by the Joint Services Lightweight Integrated Suit Technology (JSLIST) working group, specifying test methods capable of accurately measuring a protection factor greater than 1,000. This involved the use of passive sampling devices mounted beneath the clothing of the test subjects.

In each of nine trials, test subjects dressed in a protective ensemble were exposed to a high concentration of methyl salicylate (MS) vapor, a simulant for the agent mustard (HD) that has been selected for use in testing under the JSLIST program. Each exposure, to an MS concentration of 50 mg/m^3, lasted for 30 minutes.

The test subjects wore one of two suits--the Responder™ one-piece coverall with hood (part no. 41255) or the standard Army Battle Dress Overgarment (BDO). Having met requirements of the Federal Occupational Safety and Health Administration, the BDO was included in the test as a control garment with which to establish a reference

level for protection. The Responder was worn 20 times and the BDO nine times during the nine trials. The outline of the testing is shown in Table 1.

Subjects also wore a disposable Tyvek™ (spun-bonded polyolefin) coverall beneath each of the suits, as is planned to be worn beneath the Responder suit, according to the CSEPP Core Team.

Table 1. Outline of Responder Suit Testing

Trial	Order	Conditions*
1	2	Standard closures
2	4	Standard closures
3	7	Standard closures
4	9	Standard closures
5	1	Taped closures
6	8	Taped closures
7	3	Taped closures
8	6	Taped closures
9	5	Blank test-no simulant

*Up to four test subjects participated in each trial.

The Responder was tested in four configurations:

- Without integral foot-covers, wrists and ankles taped.
- Without integral foot-covers, wrists and ankles untaped.
- With integral foot-covers (Option 8A), wrists taped.
- With integral foot-covers (Option 8A), wrists untaped (one trial)

Taping involved the application of duct tape around the wrists and ankles, as shown in Figure 3, to form a tighter seal between the suit and the gloves/overboots. When suits with integral foot-covers were worn, only the wrists were taped.

In all trials with the Responder, the PAPR mask was worn in the positive-pressure mode; that is, the hood was tucked inside the suit, directing filtered air from mask into the suit. This was not done with the BDO since the BDO configuration includes the M40 mask which is a negative pressure design.

A blank test, in which no simulant was used, was also conducted.

Figure 3. Responder Suit without Integral Foot-Covers, Wrists and Ankles Taped.

4. TEST EQUIPMENT AND PROCEDURES

4.1 Facility.

Tests were conducted in the south chamber of building E5354 in the Edgewood Area of Aberdeen Proving Ground, MD. The chamber, 40 ft by 20 ft by 14 ft high, contains an evaporative-blower vapor generator controlled by a data acquisition system (DAS) with concentration readings generated by a Foxboro Miniature Infra-Red Analyzer (MIRAN™). The challenge concentration in the chamber was measured during the exposure period with the MIRAN. All MIRAN readings were recorded by the DAS.

A four-stage clean-room was erected in a bay area adjacent to the exposure chamber and was occupied by test subjects during application and removal of the sampling devices. This clean-room consisted of two airlocks and two 16-ft enclosures of the U.S. Army M28 shelter system. The enclosures, made of a chemically resistant plastic material, were pressurized with filtered air from three 200 cfm Nuclear, Biological, and Chemical (NBC) filter units of the M28, for a total clean airflow of 600 cfm. Both enclosures were monitored for MS concentrations throughout the test and during sample transfer operations using a Minicams™ automatic, real-time gas chromatograph. A layout of the test area and apparatus is shown in Figure 4.

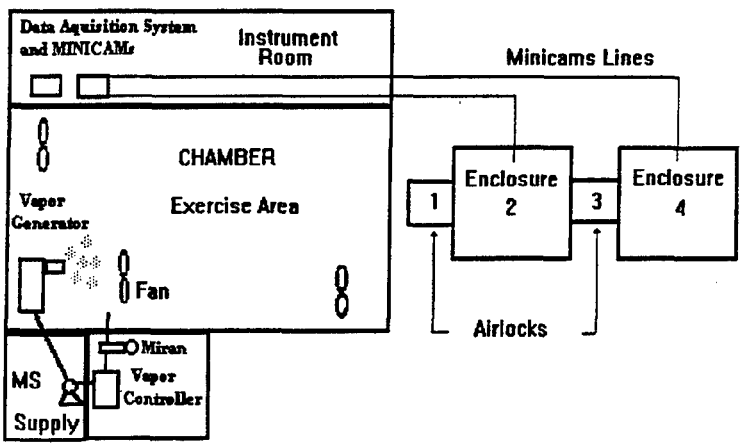

Figure 4. Chamber and Clean-Room Layout.

4.2 Air Sampling Devices for Measuring Concentration Inside Suit.

PSDs developed by the Natick Research, Development and Engineering Center (NRDEC) were used to sample for MS vapors beneath the suit. These PSDs, which contain the solid adsorbent material Tenax® TA in a small plastic (polyethylene) pouch, sample the air by capturing the MS vapors onto the adsorbent material. Contained in Appendix B is a photograph of the PSD and a technical description of its function.

The PSDs were handled with specific procedures to minimize the potential for contamination. They were applied to test subjects in the fourth stage of the clean-air room as the subjects put on the suit and were also removed in the fourth stage at the completion of each trial. After removing the PSD, the plastic pouch of the patch samplers was cut with a razor knife on one end, and a sorbent tube connected to a vacuum pump was used to remove the adsorbent from it. One end of the tube was connected by hose to a vacuum pump and the other end was inserted into the opening of the PSD to draw out the loose sorbent. A fine mesh gauze screen was then inserted into the sorbent tube (with a special gauze loading rig) and analytical end caps were placed on both ends of the tube to preclude contamination of the sample. The tube ID was recorded to ensure accurate PSD sample identification. The tubes were then analyzed with a flame ionization detector (FID) on the Perkin Elmer Sigma 2000 gas chromatograph (GC) and the ATD-50 thermal tube desorber. Background samples were also analyzed.

4.3 Applying PSDs to Test Subjects.

The PSDs were placed at 10 locations beneath the suit of each test subject, as listed below and depicted in Figure 5.

(1) Center of back, between shoulder blades
(2) Center of chest
(3) Center of back, lumbar, at upper buttocks
(4) Left axilla, on ribs
(5) Right upper arm, outer dorsum
(6) Right lower arm, outer dorsum
(7) Center of abdomen, low, into the groin area
(8) Mid-right, outer thigh
(9) Mid-right, outer lower leg
(10) Neck

The following procedures were used to apply the PSDs to test subjects to ensure minimum potential for contamination and allow measurement of the background levels of simulant during the analysis.

Dressing took place in the fourth (cleanest) stage of the clean room enclosure. Test subjects dressed in gym shorts and T-shirts before entering the clean room, were given the suit, mask, overboots, and gloves which had been pre-positioned in the clean room. The PSDs, sealed in appropriate containers, and data forms were also pre-positioned.

The PSDs were removed from the storage containers and placed on the subjects at the 10 designated locations. The PSDs, which have adhesive backing, were applied directly to the skin, or to the gym shorts or T shirt (if worn). The identification number of each PSD was recorded for each location.

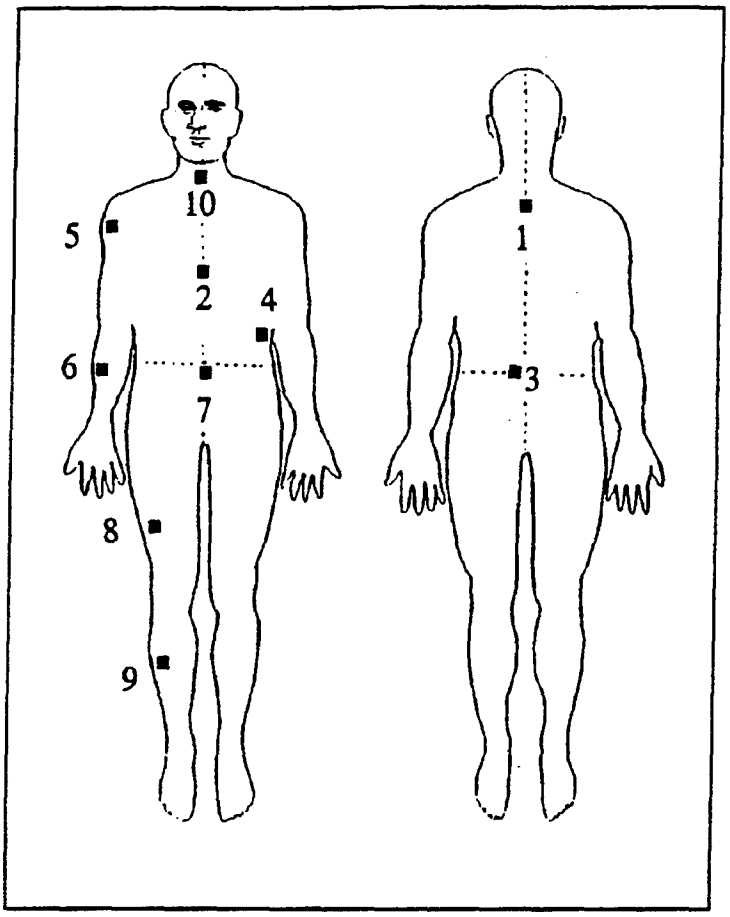

Figure 5. PSD Sample Locations.

Once initiated, the application of the PSDs was completed as rapidly as possible. Then a Tyvek coverall was donned, followed by the Responder or BDO suit, gloves, overboots, and mask. Each subject was checked to ensure proper closure and fit of the wrist closures, boot closures, front zipper/velcro closure, and hood closure. The wrist and boot closures were taped at this point if so specified by the test schedule. The subjects then proceeded out the airlock and entered the exposure chamber.

4.4 Procedures for Challenging the Suit.

The test involved a controlled sequence of steps performed to keep the samplers free of background contamination and ensure accuracy of the results. The procedure is described below.

Subjects were briefed on the test procedures and entered the clean room, enclosure 4 in Figure 4, to have the passive samplers applied and don the suit.

Once dressed, the subjects passed through the transition airlock (enclosure 3 of Figure 4), doffing room (enclosure 2 of Figure 4) and exited through the entry/exit airlock (enclosure 1 of Figure 4). The subjects were met by a test technician who escorted them into the chamber and recorded the time of entry.

The chamber was prepared by bringing the MS concentration to 50 mg/m^3 before the subjects exited the clean room. Temperature, relative humidity, and concentration readings in the chamber and in both clean-air rooms were recorded on the DAS.

Once inside the chamber, subjects performed the activities listed in Table 2. Each of these exercises was performed twice during the 30-minute exposure interval. Subjects rested for about one minute after each exercise.

Table 2. Exercise Regimen

Exercise	Time/Repetitions
Stationary run	1 minute
Jumping jacks	2 times
Trunk twister	2 times
Bend and reach	2 times
Back stretcher	2 times
Bent knee leg lifts (left and right)	10 times
Vertical reach and grasp (left and right)	1 minute
Lifting box from ground to table and return	2 times
Squat down, kneel on one knee	3 times

4.5 **Procedures for Removing PSDs.**

Because the outer garments desorb significant amounts of MS in a clean area after prolonged exposure to high concentrations of vapor, doffing took place in stages in the clean room with the following procedures.

After completing the 30 minute exercise, the subjects were escorted from the chamber and processed into the clean room in four stages (see Figure 4):

■ **Stage 1** -- Entry/exit airlock. Two pairs of subjects exited the chamber 5 minutes apart. Each pair entered the 4 ft by 4 ft airlock (enclosure 1) and set the purge timer for 5 minutes. They remained fully dressed while airflow through the airlock purged any vapor brought in with them. This period also allowed for some desorption of MS vapor from the outer surfaces of the ensemble.

■ **Stage 2** - Once inside this 16 ft by 20 ft shelter (enclosure 2), each pair of subjects removed their ensemble with the assistance of a technician. Suits, overboots, gloves and masks were placed in plastic bags to minimize the quantity of MS introduced. The subjects proceeded without delay to the next stage wearing their Tyvek coverall. This process was completed in approximately 5 minutes.

■ **Stage 3** - Transition airlock. In this 4 ft by 4 ft airlock (enclosure 3), the subjects removed the Tyvek coverall, then proceeded without delay to the final stage. This stage was completed in approximately 2 minutes.

■ **Stage 4** - In this 16 ft by 20 ft shelter (enclosure 4), the PSDs were removed from the subjects, who then exited the clean room through the transition airlock. Adsorbent was then transferred from the passive samplers to individually numbered sorbent tubes. The sorbent tubes were capped to preserve each sample for analysis.

4.6 **Procedures for Analyzing Samples**.

Sorbent tube PSDs were analyzed on the Perkin Elmer Sigma 2000 GC system, which includes the Automatic Thermal Tube Desorber (ATD-50) and the Omega data acquisition system. Details of the analysis are outlined in Appendix B.

4.7 **Process Controls**.

Tenax sorbent was certified clean before it was provided to the manufacturer of the PSDs. This certification involved heating and purging with helium in an oven at 210°C. During this period, the helium flow rate was maintained at 20 cm^3/min for a minimum of 8 hours. The adsorbent was then sampled and analyzed by gas chromatograph analysis.

Following receipt of the samplers from the manufacturer, the sorbent was sampled again. One sampler from each lot was analyzed for verification by removing the sorbent, placing it in a sorbent tube and analyzing the tube for residual levels of MS with the GC.

Quality control (QC) checks were performed each test day to ensure that the gas chromatograph was properly calibrated (calibration data are shown in Appendix A). Standard solutions containing known quantities of MS were used to verify that the mass of MS adsorbed by the PSDs was detected accurately.

The MIRAN was used to control the level of MS vapor in the chamber and was calibrated before the testing. The MIRAN calibration data are included in Appendix A.

A blank-test which involved no simulant was conducted to determine the levels of MS detected inside the suit when not exposed to the simulant MS. This trial was not conducted in the chamber, as residual levels of the simulant would have been present in the chamber.

During each pre- and post-trial period in which the PSDs were being mounted, removed, and transferred to sorbent tubes in clean room area, two PSDs

designated as "open blanks", were removed from their storage containers and exposed to the clean-room environment. These samples were analyzed to measure background levels of MS present during instrumentation, dressing, doffing, and removal of samplers and not related to the exposure in the chamber.

5. METHOD OF ANALYSIS

5.1 PSD Concentrations and Protection Factors.

The concentration of MS (C_{ms}) sampled by each interior PSD was calculated by dividing the total mass of MS on each PSD measured in the GC analysis (in μg) by the product of the sampling rate of the PSDs (in ℓ/min) multiplied by the total sampling time of each PSD (in minutes). The mass from the open background PSD samples was subtracted from each samples' mass before calculating the concentration to correct for incidental exposure of the PSDs during donning, doffing, transfer, and storage. The PSD concentration for each body area was calculated using the following equation:

$$C_{ms} = \frac{\text{Mass of MS from PSD - Mass of MS from Background}}{\text{Sampling Rate of PSD x Exposure Time}}$$

Each PSD concentration was converted to a dosage by multiplying by the exposure time. The concentration of MS in the chamber was averaged from the MIRAN data file and the total exposure dosage during each trial was calculated by multiplying by the exposure time. This value was used in the calculations of the protection factor (PF) at each body area.

Individual PFs were determined by dividing the exposure dosage by the dosage detected inside the suit at each location. The PF calculation is expressed mathematically by the following equation:

$$PF = \frac{\text{Average Exterior Concentration x Time}}{\text{Average Concentration Inside Suit x Time}} = \frac{\text{Exterior Dosage}}{\text{Dosage Inside Suit}}$$

The PF values were tabulated for each different body area.

The smallest detectable amount of MS adsorption that can be measured due by the PSD during test exposure is 5.8 ng (5.8×10^{-9} grams). Based upon an average challenge concentration of 50 mg/m^3, a 30-minute exposure period, and a PSD sampling rate of 11.6 cm^3/min, the equations listed above yield a maximum detectable PF of 3000. If the mass on a sample was less than the mass on the open background PSDs, that sampler was considered to have sampled the smallest detectable amount of MS and therefore, the maximum PF value of 3000 was assigned.

5.2 **Overall PF of Suit.**

The overall PF of the suit was determined by using the model developed by Fedele[2], which is based upon the amount of agent that must be absorbed through the skin in each of 23 different body areas to produce mean, end-point reactions. In the model, the mean end-point reaction is taken as the first significant symptom that occurs as a result of exposure to the agent. For nerve agent (VX) exposure, it is miosis (constriction of the pupil of the eye) that occurs first. Reddening of the skin, similar to severe sunburn, is the mean, end-point reaction for exposure to blister agent (HD).

The overall PF for nerve and blister agents require separate calculations. For nerve agent, the overall PF is based on a weighted average of the PF measurements from all individual body areas. This approach is used because the nerve agents produce a systemic rather than localized response in the individual. When the overall PF for nerve agent is multiplied by 10 mg-min/m^3, which is the minimum dosage of the nerve agent VX to which an unprotected individual must be exposed to develop end-point reactions, the systemic Minimum Required Exposure Dosage (MRED) value is obtained.

The initial effects of blister agent (HD) are localized to specific body areas. Furthermore, the skin in each body area has a different level of sensitivity. Because of this, the overall PF for the blister agent HD is expressed as a localized MRED. This is calculated by multiplying a local exposure dosage, which quantifies the sensitivity of the skin at a particular body region, by the PF measured at that region. The *lowest* calculated localized MRED value is applied in evaluating the suit.

A detailed description of the methods and equations used to calculate overall PF using the Fedele model is contained in Appendix B.

6. RESULTS AND DISCUSSION

6.1 **Protection Factor of Suits.**

Results of the nine trials are listed in Appendix C and are summarized in Tables 3 and 4. Tables 3 and 4 list the results of the testing according to the configuration of the protective suit. Table 3 summarizes the results with the untaped Responder and the BDO; Table 4 lists results of the Responder with taping and integral foot covers. Each table lists the test conditions, overall PF against nerve agent (VX), the systemic MREDs for nerve agent (VX), and the localized MREDs (for skin reactions to mustard) along with the skin area corresponding to the lowest localized MRED. The Systemic MREDs are simply a factor of 10 times the overall PFs. All MRED values reported hereinafter have the units of mg-min/m^3; PF values are unitless.

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[2]Fedele, Paul D., Nelson, Douglas C., *A Method of Assessing Full Individual Protective System Performance Against Vapor Challenges*, U.S. Army Edgewood Research, Development and Engineering Center, Report for Dugway under JSLIST Program, November, 1994.

Table 3. Results: Responder Suit and the BDO, Untaped and Without Integral Foot Covers

Responder Suit, Pressurized Mask, No tape, No Integral Foot Covers

		Nerve Agent Data		Blister Agent Data	
		Overall	Systemic	Local	Affected
Test	Suit Worn	PF	MRED	MRED	Body Area
2	Responder	12.7	126.8	1506	Popliteal Space
2	Responder	12.6	125.5	1473	Scrotum
2	Responder	9.4	94.2	825	Scrotum
4	Responder	26.2	261.9	2480	Popliteal Space
4	Responder	34.6	345.6	3676	Popliteal Space
4	Responder	36.0	359.6	3561	Popliteal Space
7	Responder	20.4	204.0	2576	Popliteal Space
9	Responder	94.3	943.4	7111	Popliteal Space
9	Responder	51.8	518.1	5856	Popliteal Space
	Mean:	33.1	331.0	3229	
	Std Dev:	25.2	252.1	1975	

Standard BDO, Unpressurized Mask

		Nerve Agent Data		Blister Agent Data	
		Overall	Systemic	Local	Affected
Test	Suit Worn	PF	MRED	MRED	Body Area
1	BDO	26.0	260.4	507	Scrotum
2	BDO	13.0	129.8	339	Chin and neck
3	BDO	89.5	895.3	5936	Chin and neck
4	BDO	13.5	135.0	162	Scrotum
6	BDO	26.6	266.2	555	Scrotum
7	BDO	9.7	97.0	232	Chin and neck
8	BDO	92.0	920.2	5421	Scrotum
9	BDO	35.2	351.8	978	Chin and neck
	Mean	38.2	382.0	1766	
	Std Dev:	31.4	313.9	2274	

Table 4. Results: Responder Suit, Taped and With Integral Foot Covers

Responder Suit, Taped Wrists and Ankles

		Nerve Agent Data		Blister Agent Data	
Test	Suit Worn	Overall PF	Systemic MRED	Local MRED	Affected Body Area
1	Responder	44.6	445.8	5750	Popliteal space
3	Responder	203.9	2038.8	15691	Popliteal space
3	Responder	234.2	2341.7	10164	Chin and neck
3	Responder	35.8	357.9	5070	Popliteal space
	Mean:	129.6	1296.1	9169	
	Std Dev:	90.1	901.1	4243	

Responder Suit with Integral Foot Covers, Taped Wrists

		Nerve Agent Data		Blister Agent Data	
Test	Suit Worn	Overall PF	Systemic MRED	Local MRED	Affected Body Area
6	Responder	85.2	852.3	876	Scrotum
6	Responder	378.5	3785.2	20809	Axillae
8	Responder	204.5	2044.8	77181	Elbows (back)
8	Responder	83.8	837.6	4310	Scrotum
8	Responder	297.2	2971.6	44844	
	Mean:	209.8	2098.3	29604	
	Std Dev:	116.2	1162.2	28419	

Responder Suit with Integral Foot Covers, No Taping

		Nerve Agent Data		Blister Agent Data	
Test	Suit Worn	Overall PF	Systemic MRED	Local MRED	Affected Body Area
7	Responder	71.1	711.4	4247	Chin and neck

To compare the results obtained with directing filtered air into the suit, taping the wrists and ankles, and using integral foot covers, the overall mean values from Tables 3 and 4 are consolidated in Table 5.

When worn with the Responder, the hood of the PAPR mask was worn tucked into the suit, providing filtered air to the interior of the suit. The BDO, however, was worn with the hood of the PAPR mask draped over the shoulders; thus, it did not supply filtered air into the suit. However, the hook-and-pile straps at the wrists and ankles of the BDO were fastened--the prescribed method of wearing the BDO--to achieve a seal at these locations.

The benefit of introducing filtered air to the suit is evident when the mean overall PF of the BDO is compared to configuration 2 of the Responder. With the hood tucked into the suit, the ankles or wrists were not taped, yet the overall mean PF improved to 33.1 (standard deviation 25.2), which is not significantly different from the PF of the BDO (38.2 with standard deviation 31.4). Although the BDO and Responder PFs (and systemic MREDs) were similar, the Responder had a higher mean localized MRED.

Table 5. Improvement of Chemical Protection for each Suit Configuration.

				NERVE AGENT		BLISTER AGENT	
Suit Config	Pressurized Hood/Suit?	Integral Foot Covers?	Taped?	Overall PF	Systemic MRED	Local MRED	Affected Areas
1. BDO	No	No	Yes[1]	38.2	382.0	1766	chin and neck, scrotum
2. Resp	Yes	No	No	33.1	331.0	3229	scrotum and popliteal space
3. Resp	Yes	Yes	No	71.1	711.4	4247	chin and neck
4. Resp	Yes	Yes	Yes	209.8	2098.3	29604	elbows (back), scrotum, axillae
5. Resp	Yes	No	Yes	129.6	1296.1	9169	chin and neck, popliteal space

1. Note: BDO has hook-and-pile straps at wrists and ankles.

Substantial improvements in protection were seen when the wrists and ankles of the Responder were taped. The benefit of sealing at the ankle was apparent in two sets of results. The first involved the Responder with integral foot covers, and the second involved taping the ankles without the foot covers. In both cases, the hood was tucked into the suit, directing filtered air into the suit. The mean overall PF of the ensemble with the foot covers was 71.1, more than doubling the PF of the untaped ankles. The localized MRED of this configuration was 4247. This also exceeded that of configuration 2 (local MRED of 3229). Again, the added protection of the integral foot cover was the most probable contributor. This is further substantiated by the affected body areas: Only the chin and neck areas were affected (localized response to blister agent) in Responder configuration 3, whereas the scrotum and popliteal space (regions closer to the ankle) were affected in configuration 2.

With the Responder, the benefit of additional sealing was demonstrated by results of configurations 4 and 5. In configuration 4, tape was applied at the wrists to secure a contact seal; the integral foot covers ensured a seal at the ankles without taping. In configuration 5, the Responder suit was taped at both the wrists and ankles. Taping the ankles was necessary because this suit configuration did not have the integral foot covers. The PF and MRED results for these configurations were the highest observed in

the testing. Responder configuration 4 demonstrated the highest mean overall PF of 209.8 (systemic MRED 2098.3) and highest localized MRED of 29604. Responder configuration 5 was somewhat lower in both categories with a mean overall PF of 129.6 (systemic MRED 1296.1) and a localized MRED of 9169.

The localized MRED data were analyzed to determine the most vulnerable areas for each ensemble, that is, the areas in which mustard would redden the skin first. As Table 5 shows, the lowest MRED values with the Responder occur most frequently at the popliteal space (behind the knee) and scrotum. The low MRED values for the BDO were at the chin-and-neck region and the scrotum; there were an equal number of values at each region. Low values with the BDO at the chin and neck are likely a result of the hood not being tucked into the uniform. When the wearer bent forward during his exercise routine, the hood would pull away from the uniform, momentarily providing less protection.

The region at the back of the knees had lower MRED values for the Responder suit, which indicates penetration past the elastic closures at the ankle. In contrast, the BDO has hook-and-pile fastener straps that can be adjusted to a tighter fit at the ankles. It should be noted here that the main reason these skin areas showed lower localized MREDs is that they are all sensitive skin areas; that is, these regions absorb agent at a higher rate; thus, less agent is required to cause reactions in these areas.

In summary, Table 5 shows that improvement in performance was achieved with the Responder by either taping the boots and ankles or using suits with integral foot covers. Wearing the Responder with taped ankles and wrists showed marked improvement in overall PF (from 33.1 to 129.6), Systemic MRED (from 331 to 1296), and the Localized MRED (from 3229 to 9169). Thus, when ankles and wrists were taped, overall PF was increased by a factor of 3.9 (6.3 with taped wrists and integral foot covers). There was notable improvement in the localized MRED values through taping and/or use of integral foot covers. Low MRED values at the popliteal regions were eliminated when integral foot covers were used, preventing agent vapor from entering through ankle closures.

6.2 Human Factors.

After each trial, test subjects provided comments concerning the comfort and physical performance of the ensembles. The results of the survey are summarized for each suit configuration:

6.2.1 Responder, Taped, No Foot Covers

This configuration of the Responder suit was worn four times by three of the 16 test subjects. These test subjects agreed that the taped wrist closures did not inhibit movement during the exercises and did not cause discomfort. The test subjects did complain that the taped ankles restricted leg movement during leg-lift exercises but also noted a benefit in that the taping prevented the ankle closure from slipping off the top of the boot. One subject stated that he felt hotter, possibly because the closures reduced the airflow through the suit. One subject stated that the taped ankle closure was similar in comfort to the ankle strap closure of the Toxicological Agent Protective (TAP) suit.

6.2.2 Responder, No Tape, No Foot Covers.

This configuration of the Responder suit was worn 10 times by six of the 16 test subjects. These test subjects observed that leg lift exercises were much easier to perform without the taped ankle closures. One possible deficiency was observed: that without taped ankle closures, the elastic ankle band of the suit has a tendency to slip off the top of the GVOs during leg lifts possibly affecting the vapor seal at this location.

6.2.3 Responder, Taped, Foot Covers.

This configuration of the Responder suit was worn five times by five of the 16 test subjects. No adverse comments were noted during these trials.

6.2.4 Responder, No Tape, Foot Covers.

This configuration was worn only once. The test subject participating in this trial observed that the integral foot cover restricted leg movement during leg bending and reaching exercises similar to the taped ankle closure.

6.2.5 BDO.

The BDO suit was worn nine times by six of the 16 test subjects. No complaints with the comfort of the BDO suit were recorded during these trials. One of the test subjects observed that less perspiration develops when wearing the BDO than when wearing the Responder. Another test subject encountered a problem with BDO pants, which kept sliding down at the waist because they were incorrectly fastened to the BDO jacket.

6.2.6 OptimAir 6A Powered Respirator and PAPR Hood.

All 16 test subjects wore the OptimAir 6A respirator and PAPR hood. This mask was worn 29 times during the testing. All test subjects found the mask comfortable to wear except one test subject, who stated that the rubber head harness tends to pull hair if not adjusted properly. Seven test subjects observed that the overall comfort of the mask was enhanced by the low breathing resistance. All test subjects were in favor of wearing the PAPR hood tucked into the Responder suit to create overpressure. One test subject commented that he felt a slight cooling effect in the face and neck area as the filtered air flowed into the mask, PAPR hood, and Responder suit.

7. CONCLUSIONS

When worn with the OptimAir 6A powered respirator with PAPR hood tucked into the collar, standard Army NBC gloves, and standard Army GVO, the Responder Life-Guard splash suit provides protection equivalent to or greater than that of the standard Army chemical protective overgarment (worn with the same mask, hood, gloves, and boots but without the hood tucked in). The protection provided by both garments is considered adequate for the intended CSEPP mission.

When the wrists and ankles of the suit are taped for a tighter seal, the Responder provides greater protection than the standard Army overgarment. The highest level of protection is obtained when the Responder (with the PAPR hood tucked into the collar) is worn with ankles and wrists taped or with integral foot covers and wrists taped.

Although no tests were conducted without tucking the PAPR hood into the collar, it is assumed that this configuration increases the overall protection of the ensemble by directing filtered air into the suit.

The integral foot covers and taped ankles caused minor restriction of leg motion during some movements; however, the subjects in this testing preferred the secure seal of the taped ankle or integral foot cover.

8. RECOMMENDATION

The recommended suit is the Responder worn with the PAPR hood tucked into the collar and with ankles and wrists taped. The use of integral foot covers is optional since adequate protection can be achieved with or without integral foot covers, provided the ankles are taped.

APPENDIX A
MIRAN AND GC CALIBRATION DATA

The MIRAN operated at a wavelength of 8.3 μm, a pathlength of 20.25 m, and a slit-width of 1 mm.

MIRAN Calibration Data Points

Conc mg/m^3	MIRAN Meter
0.00	0.0008
8.74	0.0456
7.76	0.0456
7.31	0.0456
21.00	0.0962
19.63	0.0962
20.52	0.0962
32.33	0.1988
35.19	0.1988
32.54	0.1988
72.43	0.3260
74.95	0.3260
70.59	0.3260
95.63	0.4847
103.88	0.4847
100.18	0.4847
176.38	0.8703
205.95	0.8703
214.08	0.8703
232.72	1.0259

Regression Output:

Constant	0
Std Err of Y Est	8.888377
R Squared	0.985943
No. of Observations	20
Degrees of Freedom	19
X Coefficient(s)	222.3934
Std Err of Coef.	4.189614

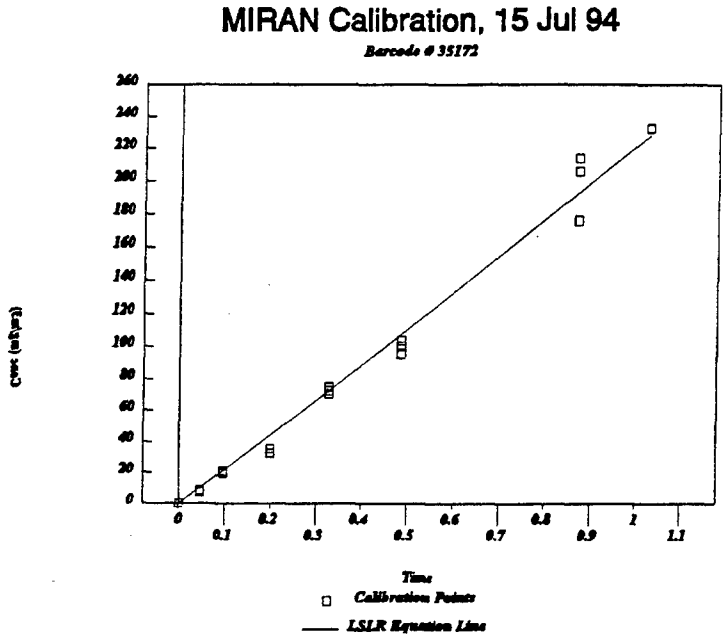

Figure A-1. MIRAN Calibration

MIRAN Calibration Barcode 35172
Range 1.0

Meter	Conc	Meter	Conc	Meter	Conc
0.01	2.224	0.41	91.181	0.81	180.139
0.02	4.448	0.42	93.405	0.82	182.363
0.03	6.672	0.43	95.629	0.83	184.587
0.04	8.896	0.44	97.853	0.84	186.810
0.05	11.120	0.45	100.077	0.85	189.034
0.06	13.344	0.46	102.301	0.86	191.258
0.07	15.568	0.47	104.525	0.87	193.482
0.08	17.791	0.48	106.749	0.88	195.706
0.09	20.015	0.49	108.973	0.89	197.930
0.10	22.239	0.50	111.197	0.90	200.154
0.11	24.463	0.51	113.421	0.91	202.378
0.12	26.687	0.52	115.645	0.92	204.602
0.13	28.911	0.53	117.869	0.93	206.826
0.14	31.135	0.54	120.092	0.94	209.050
0.15	33.359	0.55	122.316	0.95	211.274
0.16	35.583	0.56	124.540	0.96	213.498
0.17	37.807	0.57	126.764	0.97	215.722
0.18	40.031	0.58	128.988	0.98	217.946
0.19	42.255	0.59	131.212	0.99	220.169
0.20	44.479	0.60	133.436	1.00	222.393
0.21	46.703	0.61	135.660	1.01	224.617
0.22	48.927	0.62	137.884	1.02	226.841
0.23	51.150	0.63	140.108	1.03	229.065
0.24	53.374	0.64	142.332	1.04	231.289
0.25	55.598	0.65	144.556	1.05	233.513
0.26	57.822	0.66	146.780	1.06	235.737
0.27	60.046	0.67	149.004	1.07	237.961
0.28	62.270	0.68	151.228	1.08	240.185
0.29	64.494	0.69	153.451	1.09	242.409
0.30	66.718	0.70	155.675	1.10	244.633
0.31	68.942	0.71	157.899	1.11	246.857
0.32	71.166	0.72	160.123	1.12	249.081
0.33	73.390	0.73	162.347	1.13	251.305
0.34	75.614	0.74	164.571	1.14	253.529
0.35	77.838	0.75	166.795	1.15	255.752
0.36	80.062	0.76	169.019	1.16	257.976
0.37	82.286	0.77	171.243	1.17	260.200
0.38	84.510	0.78	173.467	1.18	262.424
0.39	86.733	0.79	175.691	1.19	264.648
0.40	88.957	0.80	177.915	1.20	266.872

MIRAN Calibration Barcode 35172
Range 0.25

Meter	Conc	Meter	Conc	Meter	Conc
0.01	0.556	0.41	22.795	0.81	45.035
0.02	1.112	0.42	23.351	0.82	45.591
0.03	1.668	0.43	23.907	0.83	46.147
0.04	2.224	0.44	24.463	0.84	46.703
0.05	2.780	0.45	25.019	0.85	47.259
0.06	3.336	0.46	25.575	0.86	47.815
0.07	3.892	0.47	26.131	0.87	48.371
0.08	4.448	0.48	26.687	0.88	48.927
0.09	5.004	0.49	27.243	0.89	49.483
0.10	5.560	0.50	27.799	0.90	50.039
0.11	6.116	0.51	28.355	0.91	50.595
0.12	6.672	0.52	28.911	0.92	51.150
0.13	7.228	0.53	29.467	0.93	51.706
0.14	7.784	0.54	30.023	0.94	52.262
0.15	8.340	0.55	30.579	0.95	52.818
0.16	8.896	0.56	31.135	0.96	53.374
0.17	9.452	0.57	31.691	0.97	53.930
0.18	10.008	0.58	32.247	0.98	54.486
0.19	10.564	0.59	32.803	0.99	55.042
0.20	11.120	0.60	33.359	1.00	55.598
0.21	11.676	0.61	33.915	1.01	56.154
0.22	12.232	0.62	34.471	1.02	56.710
0.23	12.788	0.63	35.027	1.03	57.266
0.24	13.344	0.64	35.583	1.04	57.822
0.25	13.900	0.65	36.139	1.05	58.378
0.26	14.456	0.66	36.695	1.06	58.934
0.27	15.012	0.67	37.251	1.07	59.490
0.28	15.568	0.68	37.807	1.08	60.046
0.29	16.124	0.69	38.363	1.09	60.602
0.30	16.680	0.70	38.919	1.10	61.158
0.31	17.235	0.71	39.475	1.11	61.714
0.32	17.791	0.72	40.031	1.12	62.270
0.33	18.347	0.73	40.587	1.13	62.826
0.34	18.903	0.74	41.143	1.14	63.382
0.35	19.459	0.75	41.699	1.15	63.938
0.36	20.015	0.76	42.255	1.16	64.494
0.37	20.571	0.77	42.811	1.17	65.050
0.38	21.127	0.78	43.367	1.18	65.606
0.39	21.683	0.79	43.923	1.19	66.162
0.40	22.239	0.80	44.479	1.20	66.718

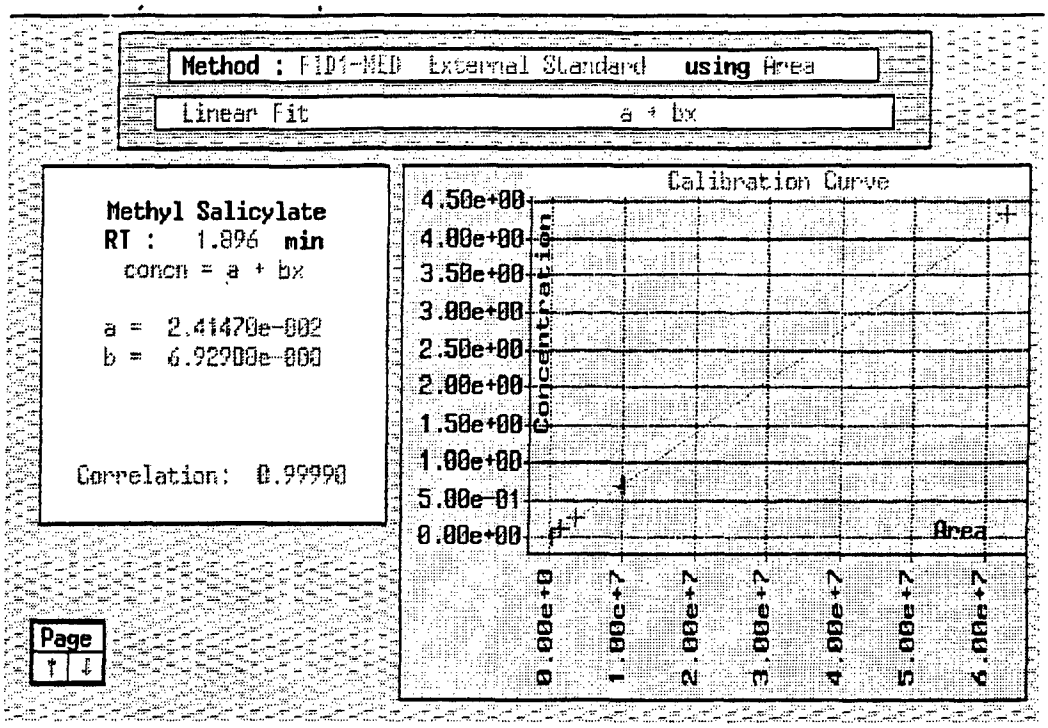

Figure A-2. Calibration Used For GC Analysis of PSD Samples.

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APPENDIX B
TECHNICAL DESCRIPTION OF TEST, MEASUREMENT, AND DIAGNOSTIC EQUIPMENT

1. Passive Sampling Device.

Shown in Figure B-1 is the NRDEC passive sampler used in this testing. This device samples the air beneath the suit by diffusion (molecular transport) with the rate of diffusion into the adsorbent (Tenax® TA) controlled by the exposed layer of polyethylene film. The sampling rate determined experimentally for the lot of PSDs used in this test was 11.6 ml/min. The adsorption velocity, or uptake rate, of the PSDs (sampling rate divided by the effective sampling surface area of 3.78 cm^2) was 3.08 cm/min. This adsorption velocity matches the skin's adsorption of agent.

B-1. Passive Sampling Device Developed by the NRDEC.

2. Gas Chromatograph Analysis.

Tubes were desorbed on the ATD-50 for 5 minutes at 250°C onto the cold trap of the ATD-50. The cold trap was then heated rapidly to 250°C and held there for 2 minutes to flush the sample from the cold trap and send it directly to the GC. The sample was separated on the GC column (6-ft, ⅛-in. stainless steel column packed with Chromosorb W HP, 100/120 mesh, liquid phase: 10% OV-17); which is held at 210°C for 4 minutes (MS elutes from the column at 1.91 minutes). The gases from the column were sent to FID, which measures the quantity given off (in millivolts) and transmits the data to the Omega computer data acquisition system, which graphs voltage (millivolts) versus time (minutes). The computer then integrated the area beneath the peaks to determine the mass of each individual component in terms of μg. The Omega system was calibrated with standards of known concentrations and uses a linear regression equation. A calibration graph is shown in Appendix A. Quality Control checks were performed each test day to ensure that the GC was functioning properly. Injections of standards was made throughout the mass range that was anticipated to be analyzed. No tubes were run unless the QC checks showed no greater than 10% variation from the mass injected.

3. Calculation of Overall Protection Factors.

Overall protection factors for each suit were calculated using the model developed by Fedele, which evaluates the amount of agent that must be absorbed percutaneously in each of 23 different areas of the human skin to produce mean, end-point reactions. This model applies data obtained from adsorption studies on human skin with pesticides[3] and the nerve agent VX[4]. A weighting factor is assigned to each of these values based on the dose and the total percentage of that skin area.

3.1 Systemic Effect - Nerve Agent (VX).

The model quantifies the dosage required to cause a systemic nerve agent effect (end-point reaction) for each body area. These dosages are listed in Table B-1 and are divided into the skin area to calculate the area/dosage (A/D) factor, which is also listed in Table B-1. The A/D factor equals the percentage of skin area divided by mass required to be absorbed at that area to produce the end-point reaction. The overall PF of the suit is determined by dividing the sum of the A/D factors by the sum of the A/(D*PF) factors (A/D factor divided by PF at each area).

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[3]Maibach et al, *Regional Variation in Percutaneous Penetration in Man*, Arch. Environ. Health, 23, pp 208-211, 1971.

[4]Sim, V.S., *Variation of Different Intact Human-Skin Sites to the Penetration of VX*, U.S. Army Chemical Research and Development Laboratories, Technical Report CRDLR 3122, 1962.

The equations used to perform these calculations are as follows:

$$(A/D)_i = A_i \div D_i$$

$$(A/D*PF)_i = A_i \div D_i \div PF_i$$

$$PF = \frac{\Sigma\,(A/D)_i}{\Sigma\,A/(D*PF)_i}$$

where, PF_i is the protection factor measured at location i = 1, 2,... 23, and PF is the overall protection factor summed over i = 1, 2, ... 23 body areas. The overall PF was then multiplied by 10 mg-min/m^3, which is the minimum dosage of the nerve agent VX to which an unprotected individual must be exposed to develop end-point reactions (miosis of the eyes occurs first). This factor is called the Minimum Required Exposure Dosage (MRED), and is used to predict dosage exposure required for systemic nerve agent effects.

3.2 Localized Effect - Blister Agent (HD).

A second set of data from the model is used to determine what exposure dosages are required to cause end-point reactions (reddening of the skin occurs first, similar to severe sunburn) when the suit wearer is exposed to HD vapor. Since the effects of HD are not cumulative and generally affect only localized body regions, the model predicts MREDs for each body region (based upon the individual PF values); and the lowest value of all these dosages is used to predict the lowest response dosage for people using the suit. Listed in Table B-1 are the local exposure dosages for HD provided by the model. The local exposure dosage column in Table B-1 contains values of agent dosages (LEDs) to which each individual skin area must be exposed to attain a localized skin reaction. These values are multiplied by the appropriate PF value to obtain the MRED required to cause localized skin reactions. Thus, the localized MRED for the suit is calculated using the following equation:

$$\text{Localized MRED} = (LED_i * PF_i)$$

where, LED_i is the localized exposure dosage for skin area i = 1,2,...23, and PF_i is the protection factor measured at skin area i = 1, 2,...23. The site with the lowest value is used in the evaluation of the data for the tests, i.e., the site with the smallest MRED value is the area that is least protected in the suit.

Table B-1. Model Parameters used to Calculate the Overall Protection Factor

Sample Region	PSD Sample Number	Skin Area (cm2)	VX Dose mg/ind	A/D Factor	Local Exposure Dosage for HD mg-min/m3
1 - Chin & Neck	10	200	0.36	556	129
2 - Ears	10	50	0.46	109	164
3 - Cheeks & Neck	10	100	0.48	208	171
4 - Nape	10	100	1.72	58	614
5 - Scalp	10	350	0.76	461	271
6 - Abdomen	2,4	2858	2.23	1282	796
7 - Back	1,4	2540	2.65	958	946
8 - Buttocks	3	953	4.26	224	1521
9 - Arms(lower,volar)	6	487	2.8	174	1000
10 - Arms(upper,volar)	5	488	2.8	174	1000
11 - Elbows (back)	5	50	2.25	22	804
12 - Arms (lower, dorsum)	6	706	6.57	107	2346
13 - Arms (upper, dorsum)	5	706	6.57	107	2346
14 - Legs (plantar, lower)	9	948	2.8	339	1000
15 - Legs (plantar, upper)	8	1422	4.26	334	1521
16 - Legs (dorsum, lower)	9	1897	6.57	289	2346
17 - Legs (dorsum, upper)	8	2845	6.57	433	2346
18 - Knees (front)	9	200	7.14	28	2550
19 - Scrotum	7	200	0.11	1818	39
20 - Groin	7	300	1.22	246	436
21 - Axillae	4	200	2.07	97	739
22 - Popliteal Space	9	100	2.09	48	746
23 - Elbowfold	6	50	2.09	24	746
		17750		8095	

APPENDIX C
PROTECTIVE SUIT TEST DATA

1. Protection Factor Test Summary.

Trial	Suit Worn	Taped?	Mask Positive Pressure?	Overall PF	Systemic MRED mg-min/m^3	Localized MRED mg-min/m^3	Area*
1	Responder	Yes	Yes	44.6	445.8	5750	22
1	BDO	No	No	26.0	260.4	507	19
2	Responder	No	Yes	12.7	126.8	1506	22
2	BDO	No	No	13.0	129.8	339	1
2	Responder	No	Yes	12.6	125.5	1473	19
2	Responder	No	Yes	9.4	94.2	825	19
3	BDO	No	No	89.5	895.3	5936	1
3	Responder	Yes	Yes	203.9	2038.8	15691	22
3	Responder	Yes	Yes	234.2	2341.7	10164	1
3	Responder	Yes	Yes	35.8	357.9	5070	22
4	Responder	No	Yes	26.2	261.9	2480	22
4	Responder	No	Yes	34.6	345.6	3676	22
4	Responder	No	Yes	36.0	359.6	3561	22
4	BDO	No	No	13.5	135.0	162	19
5	Responder	No	Yes	152.5	1524.7	3019	19
5	BDO	No	No	93.0	929.9	2740	1
6	BDO	No	No	26.6	266.2	555	19
6	Responder	Yes w/bootie	Yes	85.2	852.3	876	19
6	Responder	Yes w/bootie	Yes	378.5	3785.2	20809	21
7	Responder	No	Yes	20.4	204.0	2576	22
7	BDO	No	No	9.7	97.0	232	1
7	Responder	No w/bootie	Yes	71.1	711.4	4247	1
8	Responder	Yes w/bootie	Yes	204.5	2044.8	77181	11
8	Responder	Yes w/bootie	Yes	83.8	837.6	4310	19
8	Responder	Yes w/bootie	Yes	297.2	2971.6	44844	19
8	BDO	No	No	92.0	920.2	5421	19
9	Responder	No	Yes	94.3	943.4	7111	22
9	Responder	No	Yes	51.8	518.1	5856	22
9	BDO	No	No	35.2	351.8	978	1

*Areas are: 1 - Chin & Neck; 11 - Elbows (back); 19 - Scrotum; 21 - Axillae; 22 - Popliteal Space.

2. Detailed Protection Factor Test Data for Each Trial.

Responder Suit Protection Factor Test 1 19 June 95

Subject 1: Responder, taped at wrists & ankles

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	R1	0.0116	30.00	0.341	0.5525	17.682	93.1
1 Back	R2	0.0116	30.00	0.623	1.3610	43.551	37.8
1 Back	R3	0.0116	30.00	0.585	1.2533	40.105	41.0
2 Chest	R4	0.0116	30.00	0.146	BBL*	BBL	3000.0
3 Buttocks	R5	0.0116	30.00	0.347	0.5703	18.250	90.2
4 Axilla	R6	0.0116	30.00	1.433	3.6823	117.833	14.0
5 Upper Arm	R7	0.0116	30.00	1.770	4.6459	148.669	11.1
6 Lower Arm	R8	0.0116	30.00	0.089	BBL	BBL	3000.0
7 Crotch	R9	0.0116	30.00	0.252	0.2991	9.572	172.0
8 Thigh	R10	0.0116	30.00	0.643	1.4188	45.402	36.3
9 Lower Leg	R11	0.0116	30.00	2.478	6.6734	213.549	7.7
10 Neck	R12	0.0116	30.00	0.167	0.0551	1.764	933.1

Subject 2: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	R13	0.0116	30.00	0.258	0.3151	10.085	163.2
1 Back	R14	0.0116	30.00	0.395	0.7080	22.658	72.6
1 Back	R15	0.0116	30.00	0.788	1.8335	58.671	28.1
2 Chest	R16	0.0116	30.00	2.228	5.9563	190.603	8.6
3 Buttocks	R17	0.0116	30.00	0.184	0.1035	3.313	496.9
4 Axilla	R18	0.0116	30.00	0.621	1.3558	43.386	37.9
5 Upper Arm	R19	0.0116	30.00	0.144	BBL	BBL	3000.0
6 Lower Arm	R20	0.0116	30.00	0.389	0.6903	22.089	74.5
7 Crotch	R21	0.0116	30.00	1.530	3.9595	126.703	13.0
8 Thigh	R22O	0.0116	30.00	0.155	0.0208	0.664	2477.5
9 Lower Leg	SH9	0.0116	30.00	0.340	0.5505	17.617	93.4
10 Neck	CH17	0.0116	30.00	1.082	2.6748	85.595	19.2

Patch BK	B3	0.018	30.00	0.192	0.3559
Patch BK	B4	0.018	30.00	0.103	0.1906
			Avg:	0.14755	

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m^3)
	32	1646	51.44

* BBL = Below Background Level

Responder Test 1, 19 Jun 95

Skin Area Region	Subject 1 Values Responder, taped PF	A (D*PF)	Localized MRED mg-min/m³	Subject 2 Values BDO PF	A (D*PF)	Localized MRED mg-min/m³
1 Chin & Neck	933	0.6	120369	19	28.9	2481
2 Ears	933	0.1	153027	19	5.7	3154
3 Cheeks & Neck	933	0.2	159558	19	10.8	3288
4 Nape	933	0.1	572917	19	3.0	11807
5 Scalp	933	0.5	252867	19	23.9	5211
6 Abdomen	8237	0.2	6556640	23	55.0	18537
7 Back	54	17.9	50640	101	9.5	95146
8 Buttocks	90	2.5	137184	497	0.5	755745
9 Arms (lower, volar)	3000	0.1	3000000	75	2.3	74516
10 Arms (upper, volar)	11	15.7	11072	3000	0.1	3000000
11 Elbows (back)	11	2.0	8902	3000	0.0	2412000
12 Arms (lower, dorsum)	3000	0.0	7038000	75	1.4	174813
13 Arms (upper, dorsum)	11	9.7	25974	3000	0.0	7038000
14 Legs (plantar, lower)	8	43.9	7708	93	3.6	93430
15 Legs (plantar, upper)	36	9.2	55142	2478	0.1	3768298
16 Legs (dorsum, lower)	8	37.5	18083	93	3.1	219187
17 Legs (dorsum, upper)	36	11.9	85052	2478	0.2	5812247
18 Knees (front)	8	3.6	19655	93	0.3	238247
19 **Scrotum**	172	10.6	6707	13	140.0	**507**
20 Groin	172	1.4	74978	13	18.9	5664
21 Axillae	14	6.9	10323	38	2.5	28037
22 **Popliteal Space**	8	6.2	**5750**	93	0.5	69699
23 Elbowfold	3000	0.0	2238000	75	0.3	55589
		181.6			310.8	
Overall PF:	**44.6**			**26.0**		
Systemic MRED:	**445.8**			**260.4**		

Responder Suit Protection Factor Test 2 20 June 95

Subject 1: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	A5	0.0116	30.00	1.534	3.5485	106.456	14.3
1 Back	C13O	0.0116	30.00	0.464	0.4855	14.566	104.7
1 Back	C15O	0.0116	30.00	0.295	0.0010	0.030	50700.5
2 Chest	A6	0.0116	30.00	0.162	BBL*	BBL	3000.0
3 Buttocks	A8	0.0116	30.00	0.748	1.2988	38.965	39.1
4 Axilla	CA4	0.0116	30.00	0.285	BBL	BBL	3000.0
5 Upper Arm	CA5	0.0116	30.00	0.663	1.0551	31.654	48.2
6 Lower Arm	CA6	0.0116	30.00	2.108	5.1929	155.786	9.8
7 Crotch	CA7	0.0116	30.00	0.426	0.3753	11.259	135.4
8 Thigh	C9	0.0116	30.00	5.611	15.2247	456.740	3.3
9 Lower Leg	C10	0.0116	30.00	9.083	25.1668	755.004	2.0
10 Neck	C12	0.0116	30.00	0.314	0.0537	1.611	946.4

Subject 2: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	CH1	0.0116	30.00	0.680	1.1038	33.114	46.0
1 Back	CH13	0.0116	30.00	0.098	BBL	BBL	3000.0
1 Back	CH14O	0.0116	30.00	0.469	0.4981	14.944	102.0
2 Chest	CH2	0.0116	30.00	0.438	0.4097	12.290	124.0
3 Buttocks	CH3	0.0116	30.00	0.531	0.6757	20.271	75.2
4 Axilla	CH5	0.0116	30.00	0.082	BBL	BBL	3000.0
5 Upper Arm	CH6	0.0116	30.00	0.208	BBL	BBL	3000.0
6 Lower Arm	CH7	0.0116	30.00	2.034	4.9807	149.420	10.2
7 Crotch	CH8	0.0116	30.00	0.376	0.2324	6.972	218.7
8 Thigh	CH9	0.0116	30.00	0.598	0.8690	26.070	58.5
9 Lower Leg	CH11	0.0116	30.00	1.258	2.7579	82.736	18.4
10 Neck	CH12	0.0116	30.00	7.039	19.3146	579.437	2.6
Patch BK	B3	0.018	30.00	0.371	0.6863		
Patch BK	B4	0.018	30.00	0.219	0.4054		
			Avg:	0.29475			

Data Acquisition System	# Mins	Dosage	Avg Conc** (mg/m³)
	30	1524.5	50.82

* BBL = Below Background Level
** External Challenge Concentration

Responder Suit Protection Factor Test 2 20 June 95

Subject 3: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	H1-O	0.0116	30.00	1.164	2.4884	74.652	20.4
1 Back	H11	0.0116	30.00	1.614	3.7788	113.363	13.4
1 Back	H14	0.0116	30.00	1.432	3.2579	97.736	15.6
2 Chest	H2	0.0116	30.00	0.347	0.1502	4.506	338.3
3 Buttocks	H3-O	0.0116	30.00	0.560	0.7587	22.762	67.0
4 Axilla	H4-O	0.0116	30.00	1.492	3.4283	102.848	14.8
5 Upper Arm	H5	0.0116	30.00	0.866	1.6356	49.068	31.1
6 Lower Arm	H4A	0.0116	30.00	2.638	6.7109	201.327	7.6
7 Crotch	H7	0.0116	30.00	0.765	1.3452	40.357	37.8
8 Thigh	H8	0.0116	30.00	2.786	7.1345	214.034	7.1
9 Lower Leg	H9-O	0.0116	30.00	8.793	24.3358	730.073	2.1
10 Neck	H10	0.0116	30.00	0.520	0.6450	19.351	78.8

Subject 4: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	N2	0.0116	30.00	0.264	BBL*	BBL	3000.0
1 Back		0.0116	30.00	0.264	BBL	BBL	3000.0
1 Back		0.0116	30.00	0.264	BBL	BBL	3000.0
2 Chest	N3	0.0116	30.00	0.437	0.4062	12.186	125.1
3 Buttocks	N4	0.0116	30.00	1.040	2.1342	64.025	23.8
4 Axilla	N5	0.0116	30.00	0.197	BBL	BBL	3000.0
5 Upper Arm	N7	0.0116	30.00	0.468	0.4967	14.901	102.3
6 Lower Arm	N8	0.0116	30.00	3.164	8.2164	246.491	6.2
7 Crotch	N9	0.0116	30.00	1.134	2.4022	72.066	21.2
8 Thigh	N10	0.0116	30.00	5.283	14.2851	428.552	3.6
9 Lower Leg	N11	0.0116	30.00	8.497	23.4875	704.626	2.2
10 Neck	N13	0.0116	30.00	2.319	5.7980	173.939	8.8

Data Acquisition System	# Mins	Dosage	Avg Conc** (mg/m^3)
	30.00	1524.50	50.82

* BBL = Below Background Level

** External Challenge Concentration

Responder Test 2, 20 Jun 95

	Subject 1 Values Responder			Subject 2 Values BDO		
Skin Area Region	PF	A (D*PF)	Localized MRED mg-min/m^3	PF	A (D*PF)	Localized MRED mg-min/m^3
1 **Chin & Neck**	946	0.6	122087	3	211.2	**339**
2 Ears	946	0.1	155211	3	41.3	431
3 Cheeks & Neck	946	0.2	161836	3	79.2	450
4 Nape	946	0.1	581095	3	22.1	1615
5 Scalp	946	0.5	256477	3	175.0	713
6 Abdomen	3000	0.4	2388000	1562	0.8	1243371
7 Back	9970	0.1	9431540	2025	0.5	1915343
8 Buttocks	39	5.7	59509	75	3.0	114390
9 Arms (lower, volar)	10	17.8	9786	10	17.0	10203
10 Arms (upper, volar)	48	3.6	48162	3000	0.1	3000000
11 Elbows (back)	48	0.5	38722	3000	0.0	2412000
12 Arms (lower, dorsum)	10	11.0	22958	10	10.5	23936
13 Arms (upper, dorsum)	48	2.2	112987	3000	0.0	7038000
14 Legs (plantar, lower)	2	167.7	2019	18	18.4	18426
15 Legs (plantar, upper)	3	100.0	5077	58	5.7	88945
16 Legs (dorsum, lower)	2	143.0	4737	18	15.7	43227
17 Legs (dorsum, upper)	3	129.7	7830	58	7.4	137190
18 Knees (front)	2	13.9	5149	18	1.5	46986
19 Scrotum	135	13.4	5281	219	8.3	8528
20 Groin	135	1.8	59038	219	1.1	95341
21 Axillae	3000	0.0	2217000	3000	0.0	2217000
22 **Popliteal Space**	2	23.7	**1506**	18	2.6	13746
23 Elbowfold	10	2.4	7300	10	2.3	7611
		638.5			623.8	
Overall PF:	**12.7**			**13.0**		
Systemic MRED:	**126.8**			**129.8**		

Responder Test 2, 20 Jun 95

Skin Area Region	Subject 3 Values Responder PF	A (D*PF)	Localized MRED mg-min/m³	Subject 4 Values Responder PF	A (D*PF)	Localized MRED mg-min/m³
1 Chin & Neck	79	7.1	10163	9	63.4	1131
2 Ears	79	1.4	12920	9	12.4	1437
3 Cheeks & Neck	79	2.6	13471	9	23.8	1499
4 Nape	79	0.7	48371	9	6.6	5381
5 Scalp	79	5.8	21349	9	52.5	2375
6 Abdomen	177	7.3	140553	1563	0.8	1243789
7 Back	16	61.2	14811	3000	0.3	2838000
8 Buttocks	67	3.3	101870	24	9.4	36217
9 Arms (lower, volar)	8	23.0	7572	6	28.1	6185
10 Arms (upper, volar)	31	5.6	31069	102	1.7	102307
11 Elbows (back)	31	0.7	24980	102	0.2	82255
12 Arms (lower, dorsum)	8	14.2	17764	6	17.4	14510
13 Arms (upper, dorsum)	31	3.5	72888	102	1.1	240013
14 Legs (plantar, lower)	2	162.1	2088	2	156.5	2164
15 Legs (plantar, upper)	7	46.9	10834	4	93.8	5411
16 Legs (dorsum, lower)	2	138.3	4899	2	133.5	5076
17 Legs (dorsum, upper)	7	60.8	16710	4	121.7	8345
18 Knees (front)	2	13.4	5325	2	12.9	5517
19 **Scrotum**	38	48.1	**1473**	21	85.9	**825**
20 Groin	38	6.5	16470	21	11.6	9223
21 Axillae	15	6.5	10954	3000	0.0	2217000
22 Popliteal Space	2	22.9	1558	2	22.1	1614
23 Elbowfold	8	3.2	5649	6	3.9	4614
		645.1			859.8	
Overall PF:	**12.6**			**9.4**		
Systemic MRED:	**125.5**			**94.2**		

Responder Suit Protection Factor Test 3 21 June 95

Subject 1: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	R1	0.0116	30.00	0.557	1.0361	31.082	50.3
1 Back	R11	0.0116	30.00	0.216	0.0587	1.761	888.2
1 Back	R12	0.0116	30.00	0.187	BBL*	BBL	3000.0
2 Chest	R2	0.0116	30.00	0.167	BBL	BBL	3000.0
3 Buttocks	R3	0.0116	30.00	1.249	3.0155	90.464	17.3
4 Axilla	R4-lost	0.0116	30.00	0.000	BBL	BBL	3000.0
5 Upper Arm	R5	0.0116	30.00	0.857	1.8935	56.804	27.5
6 Lower Arm	R6	0.0116	30.00	0.216	0.0593	1.778	879.6
7 Crotch	R7	0.0116	30.00	0.107	BBL	BBL	3000.0
8 Thigh	R8	0.0116	30.00	0.191	BBL	BBL	3000.0
9 Lower Leg	R9	0.0116	30.00	1.076	2.5226	75.679	20.7
10 Neck	R10-lost	0.0116	30.00	0.591	1.1332	33.995	46.0

Subject 2: Responder, taped at wrists & ankles

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	R13	0.0116	30.00	0.180	BBL	BBL	3000.0
1 Back	H10	0.0116	30.00	0.626	1.2331	36.993	42.3
1 Back	H11	0.0116	30.00	0.259	0.1813	5.438	287.7
2 Chest	R14	0.0116	30.00	0.203	0.0215	0.644	2427.8
3 Buttocks	R15	0.0116	30.00	0.170	BBL	BBL	3000.0
4 Axilla	R16	0.0116	30.00	0.214	0.0536	1.607	973.7
5 Upper Arm	R17	0.0116	30.00	0.208	0.0349	1.048	1492.5
6 Lower Arm	R18	0.0116	30.00	0.224	0.0819	2.457	636.7
7 Crotch	R19	0.0116	30.00	0.191	BBL	BBL	3000.0
8 Thigh	R20	0.0116	30.00	0.238	0.1226	3.677	425.4
9 Lower Leg	R21	0.0116	30.00	1.061	2.4791	74.373	21.0
10 Neck	R22	0.0116	30.00	0.212	0.0470	1.409	1110.3
Patch BK	B3	0.018	30.00	0.223	0.4135		
Patch BK	B4	0.018	30.00	0.168	0.3106		
			Avg:	0.1955			

Data Acquisition System	# Mins	Dosage	Avg Conc** (mg/m^3)
	30	1564.3	52.20

* BBL = Below Background Level
** External Challenge Concentration

Responder Suit Protection Factor Test 3 21 June 95

Subject 3: Responder, taped at wrists & ankles

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	C1	0.0116	30.00	0.257	0.1747	5.241	298.5
1 Back	A3 lost	0.0116	30.00	0.101	BBL	BBL	3000.0
1 Back	A4	0.0116	30.00	0.207	0.0341	1.022	1530.1
2 Chest	C2	0.0116	30.00	0.268	0.2065	6.194	252.5
3 Buttocks	C3	0.0116	30.00	0.099	BBL	BBL	3000.0
4 Axilla	C5	0.0116	30.00	0.120	BBL	BBL	3000.0
5 Upper Arm	C8	0.0116	30.00	0.191	BBL	BBL	3000.0
6 Lower Arm	C11	0.0116	30.00	0.191	BBL	BBL	3000.0
7 Crotch	C14	0.0116	30.00	0.198	0.0060	0.180	8670.7
8 Thigh	C16	0.0116	30.00	0.419	0.6406	19.218	81.4
9 Lower Leg	A1	0.0116	30.00	0.344	0.4255	12.766	122.5
10 Neck	A2	0.0116	30.00	0.427	0.6618	19.854	78.8

Subject 4: Responder, taped at wrists & ankles

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	ST1	0.0116	30.00	0.657	1.3219	39.656	39.4
1 Back	T4	0.0116	30.00	0.469	0.7838	23.514	66.5
1 Back	T5	0.0116	30.00	0.753	1.5956	47.869	32.7
2 Chest	ST2	0.0116	30.00	0.245	0.1409	4.227	370.1
3 Buttocks	ST3	0.0116	30.00	0.163	BBL	BBL	3000.0
4 Axilla	ST4	0.0116	30.00	0.468	0.7792	23.376	66.9
5 Upper Arm	ST5	0.0116	30.00	0.250	0.1558	4.674	334.7
6 Lower Arm	HL2-L	0.0116	30.00	0.191	BBL	BBL	3000.0
7 Crotch	H12	0.0116	30.00	0.136	BBL	BBL	3000.0
8 Thigh	H15	0.0116	30.00	1.855	4.7523	142.569	11.0
9 Lower Leg	H17	0.0116	30.00	2.875	7.6730	230.189	6.8
10 Neck	H19	0.0116	30.00	0.546	1.0046	30.137	51.9
						0.100	15643.

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m³)
	30.00	1564.30	52.20

Responder Test 3, 21 Jun 95

Skin Area Region	Subject 1 Values BDO PF	A (D*PF)	Localized MRED mg-min/m^3	Subject 2 Values Responder, taped PF	A (D*PF)	Localized MRED mg-min/m^3
1 **Chin & Neck**	46	12.1	**5936**	1110	0.5	143225
2 Ears	46	2.4	7547	1110	0.1	182085
3 Cheeks & Neck	46	4.5	7869	1110	0.2	189856
4 Nape	46	1.3	28254	1110	0.1	681707
5 Scalp	46	10.0	12470	1110	0.4	300884
6 Abdomen	3000	0.4	2388000	1701	0.8	1353800
7 Back	2156	0.4	2039977	1042	0.9	985587
8 Buttocks	17	12.9	26301	3000	0.1	4563000
9 Arms (lower, volar)	880	0.2	879635	637	0.3	636659
10 Arms (upper, volar)	28	6.3	27538	1492	0.1	1492496
11 Elbows (back)	28	0.8	22141	1492	0.0	1199967
12 Arms (lower, dorsum)	880	0.1	2063625	637	0.2	1493602
13 Arms (upper, dorsum)	28	3.9	64605	1492	0.1	3501396
14 Legs (plantar, lower)	21	16.4	20670	21	16.1	21033
15 Legs (plantar, upper)	3000	0.1	4563000	425	0.8	647081
16 Legs (dorsum, lower)	21	14.0	48492	21	13.7	49344
17 Legs (dorsum, upper)	3000	0.1	7038000	425	1.0	998061
18 Knees (front)	21	1.4	52709	21	1.3	53635
19 Scrotum	3000	0.6	117000	3000	0.6	117000
20 Groin	3000	0.1	1308000	3000	0.1	1308000
21 Axillae	3000	0.0	2217000	974	0.1	719575
22 **Popliteal Space**	21	2.3	15420	21	2.3	**15691**
23 Elbowfold	880	0.0	656208	637	0.0	474948
	90.4		39.7			
Overall PF:	**89.5**			**203.9**		
Systemic MRED:	**895.3**			**2038.8**		

Responder Test 3, 21 Jun 95

Skin Area Region	Subject 3 Values Responder, taped PF	A (D*PF)	Localized MRED mg-min/m³	Subject 4 Values Responder, taped PF	A (D*PF)	Localized MRED mg-min/m³
1 **Chin & Neck**	79	7.1	**10164**	52	10.7	6696
2 Ears	79	1.4	12922	52	2.1	8513
3 Cheeks & Neck	79	2.6	13473	52	4.0	8876
4 Nape	79	0.7	48377	52	1.1	31870
5 Scalp	79	5.8	21352	52	8.9	14066
6 Abdomen	1626	0.8	1294513	219	5.9	173929
7 Back	2305	0.4	2180313	57	16.9	53513
8 Buttocks	3000	0.1	4563000	3000	0.1	4563000
9 Arms (lower, volar)	3000	0.1	3000000	3000	0.1	3000000
10 Arms (upper, volar)	3000	0.1	3000000	335	0.5	334714
11 Elbows (back)	3000	0.0	2412000	335	0.1	269110
12 Arms (lower, dorsum)	3000	0.0	7038000	3000	0.0	7038000
13 Arms (upper, dorsum)	3000	0.0	7038000	335	0.3	785239
14 Legs (plantar, lower)	123	2.8	122533	7	49.8	6796
15 Legs (plantar, upper)	81	4.1	123804	11	30.4	16689
16 Legs (dorsum, lower)	123	2.4	287463	7	42.5	15943
17 Legs (dorsum, upper)	81	5.3	190957	11	39.5	25741
18 Knees (front)	123	0.2	312460	7	4.1	17329
19 Scrotum	8671	0.2	338157	3000	0.6	117000
20 Groin	8671	0.0	3780421	3000	0.1	1308000
21 Axillae	3000	0.0	2217000	67	1.4	49453
22 **Popliteal Space**	123	0.4	91410	7	7.0	**5070**
23 Elbowfold	3000	0.0	2238000	3000	0.0	2238000
	34.6		226.2			
Overall PF:	**234.2**			**35.8**		
Systemic MRED:	**2341.7**			**357.9**		

Responder Suit Protection Factor Test 4 22 June 95

Subject 1: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	CA4	0.0116	30.00	0.278	BBL*	BBL	3000.0
1 Back	A9	0.0116	30.00	0.081	BBL	BBL	3000.0
1 Back	A10	0.0116	30.00	0.079	BBL	BBL	3000.0
2 Chest	CA5	0.0116	30.00	0.167	BBL	BBL	3000.0
3 Buttocks	CA6	0.0116	30.00	2.682	6.4731	194.192	7.9
4 Axilla	CA7	0.0116	30.00	0.078	BBL	BBL	3000.0
5 Upper Arm	CA8	0.0116	30.00	0.441	0.0533	1.598	965.0
6 Lower Arm	A4	0.0116	30.00	1.506	3.1054	93.162	16.6
7 Crotch	A5	0.0116	30.00	0.200	BBL	BBL	3000.0
8 Thigh	A6	0.0116	30.00	1.561	3.2615	97.844	15.8
9 Lower Leg	A7	0.0116	30.00	5.822	15.4631	463.892	3.3
10 Neck	A8	0.0116	30.00	0.133	BBL	BBL	3000.0

Subject 2: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	CH1	0.0116	30.00	0.235	BBL	BBL	3000.0
1 Back	CH13	0.0116	30.00	0.499	0.2214	6.641	232.2
1 Back	CH14	0.0116	30.00	0.514	0.2649	7.947	194.0
2 Chest	CH2	0.0116	30.00	1.571	3.2904	98.711	15.6
3 Buttocks	CH3	0.0116	30.00	0.070	BBL	BBL	3000.0
4 Axilla	CH5	0.0116	30.00	0.059	BBL	BBL	3000.0
5 Upper Arm	CH6	0.0116	30.00	0.086	BBL	BBL	3000.0
6 Lower Arm	CH7	0.0116	30.00	0.309	BBL	BBL	3000.0
7 Crotch	CH8	0.0116	30.00	0.110	BBL	BBL	3000.0
8 Thigh	CH9	0.0116	30.00	1.745	3.7878	113.634	13.6
9 Lower Leg	CH11	0.0116	30.00	4.064	10.4298	312.895	4.9
10 Neck	CH12	0.0116	30.00	0.844	1.2088	36.263	42.5
Patch	BKX4	0.018	30.00	0.779	1.4422		
Patch BK	X5	0.018	30.00	0.065	0.1204		
Avg:				0.4219			

Data Acquisition System	# Mins	Dosage (mg/m^3)	Avg Conc**
	30	1542	51.35

* BBL = Below Background Level
** External Challenge Concentration

Responder Suit Protection Factor Test 4 22 June 95

Subject 3: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	H1	0.0116	30.00	0.067	BBL*	BBL	3000.0
1 Back	H10	0.0116	30.00	2.790	6.7812	203.436	7.6
1 Back	H11	0.0116	30.00	0.077	BBL	BBL	3000.0
2 Chest	H2	0.0116	30.00	0.064	BBL	BBL	3000.0
3 Buttocks	H3	0.0116	30.00	0.115	BBL	BBL	3000.0
4 Axilla	H4	0.0116	30.00	0.113	BBL	BBL	3000.0
5 Upper Arm	H4A	0.0116	30.00	0.186	BBL	BBL	3000.0
6 Lower Arm	H5	0.0116	30.00	0.163	BBL	BBL	3000.0
7 Crotch	H5A	0.0116	30.00	0.097	BBL	BBL	3000.0
8 Thigh	H7	0.0116	30.00	2.190	5.0641	151.924	10.1
9 Lower Leg	H8	0.0116	30.00	4.182	10.7675	323.024	4.8
10 Neck	H9	0.0116	30.00	0.070	BBL	BBL	3000.0

Subject 4: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	N2	0.0116	30.00	0.491	0.1967	5.902	261.3
1 Back	N15	0.0116	30.00	0.243	BBL	BBL	3000.0
1 Back	N16	0.0116	30.00	0.090	BBL	BBL	3000.0
2 Chest	N3	0.0116	30.00	0.130	BBL	BBL	3000.0
3 Buttocks	N4 O	0.0116	30.00	1.987	4.4814	134.442	11.5
4 Axilla	N5	0.0116	30.00	1.188	2.1927	65.782	23.4
5 Upper Arm	N8	0.0116	30.00	1.631	3.4636	103.909	14.8
6 Lower Arm	N9	0.0116	30.00	0.086	BBL	BBL	3000.0
7 Crotch	N10	0.0116	30.00	4.746	12.3820	371.460	4.2
8 Thigh	N11	0.0116	30.00	0.157	BBL	BBL	3000.0
9 Lower Leg	N13	0.0116	30.00	0.283	BBL	BBL	3000.0
10 Neck	N14	0.0116	30.00	1.142	2.0630	61.890	
						0.100	15420.0

Data Acquisition System	# Mins	Dosage	Avg Conc** (mg/m³)
	30.00	1542.00	51.35

* BBL = Below Background Level
** External Challenge Concentration

Responder Test 4, 22 Jun 95

Skin Area Region	Subject 1 Values Responder PF	A (D*PF)	Localized MRED mg-min/m^3	Subject 2 Values Responder PF	A (D*PF)	Localized MRED mg-min/m^3
1 Chin & Neck	3000	0.2	387000	43	13.1	5485
2 Ears	3000	0.0	492000	43	2.6	6974
3 Cheeks & Neck	3000	0.1	513000	43	4.9	7271
4 Nape	3000	0.0	1842000	43	1.4	26109
5 Scalp	3000	0.2	813000	43	10.8	11524
6 Abdomen	3000	0.4	2388000	1508	0.8	1200217
7 Back	3000	0.3	2838000	2071	0.5	1959204
8 Buttocks	8	28.2	12078	3000	0.1	4563000
9 Arms (lower, volar)	17	10.5	16552	3000	0.1	3000000
10 Arms (upper, volar)	965	0.2	964994	3000	0.1	3000000
11 Elbows (back)	965	0.0	775855	3000	0.0	2412000
12 Arms (lower, dorsum)	17	6.5	38831	3000	0.0	7038000
13 Arms (upper, dorsum)	965	0.1	2263875	3000	0.0	7038000
14 Legs (plantar, lower)	3	101.9	3324	5	68.7	4928
15 Legs (plantar, upper)	16	21.2	23971	14	24.6	20640
16 Legs (dorsum, lower)	3	86.9	7798	5	58.6	11561
17 Legs (dorsum, upper)	16	27.5	36973	14	31.9	31835
18 Knees (front)	3	8.4	8476	5	5.7	12567
19 Scrotum	3000	0.6	117000	3000	0.6	117000
20 Groin	3000	0.1	1308000	3000	0.1	1308000
21 Axillae	3000	0.0	2217000	3000	0.0	2217000
22 **Popliteal Space**	3	14.4	**2480**	5	9.7	**3676**
23 Elbowfold	17	1.4	12348	3000	0.0	2238000
		309.1			234.2	
Overall PF:	**26.2**			**34.6**		
Systemic MRED:	**261.9**			**345.6**		

Responder Test 4, 22 Jun 95

Skin Area Region	Subject 3 Values Responder PF	A (D*PF)	Localized MRED mg-min/m³	Subject 4 Values BDO PF	A (D*PF)	Localized MRED mg-min/m³
1 Chin & Neck	3000	0.2	387000	25	22.3	3214
2 Ears	3000	0.0	492000	25	4.4	4086
3 Cheeks & Neck	3000	0.1	513000	25	8.4	4260
4 Nape	3000	0.0	1842000	25	2.3	15298
5 Scalp	3000	0.2	813000	25	18.5	6752
6 Abdomen	3000	0.4	2388000	1512	0.8	1203330
7 Back	2501	0.4	2366195	1055	0.9	998280
8 Buttocks	3000	0.1	4563000	11	19.5	17445
9 Arms (lower, volar)	3000	0.1	3000000	3000	0.1	3000000
10 Arms (upper, volar)	3000	0.1	3000000	15	11.7	14840
11 Elbows (back)	3000	0.0	2412000	15	1.5	11931
12 Arms (lower, dorsum)	3000	0.0	7038000	3000	0.0	7038000
13 Arms (upper, dorsum)	3000	0.0	7038000	15	7.2	34814
14 Legs (plantar, lower)	5	70.9	477	3000	0.1	3000000
15 Legs (plantar, upper)	10	32.9	15438	3000	0.1	4563000
16 Legs (dorsum, lower)	5	60.5	11199	3000	0.1	7038000
17 Legs (dorsum, upper)	10	42.7	23811	3000	0.1	7038000
18 Knees (front)	5	5.9	12173	3000	0.0	7650000
19 **Scrotum**	3000	0.6	117000	4	438.0	**162**
20 Groin	3000	0.1	1308000	4	59.2	1810
21 Axillae	3000	0.0	2217000	23	4.1	17323
22 **Popliteal Space**	5	10.0	**3561**	3000	0.0	2238000
23 Elbowfold	3000	0.0	2238000	3000	0.0	2238000
	225.1				599.5	
Overall PF:	**36.0**			**13.5**		
Systemic MRED:	**359.6**			**135.0**		

Responder Suit Protection Factor Test 5 23 June 95

Subject 1: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	R1	0.0116	30.00	0.038	BBL	BBL	3000.0
1 Back	R11	0.0116	30.00	0.071	BBL	BBL	3000.0
1 Back	R12	0.0116	30.00	0.079	BBL	BBL	3000.0
2 Chest	R2	0.0116	30.00	0.164	0.1029	3.088	499.3
3 Buttocks	R3	0.0116	30.00	0.272	0.4097	12.290	125.5
4 Axilla	R4	0.0116	30.00	0.430	0.8630	25.889	59.6
5 Upper Arm	R5	0.0116	30.00	0.227	0.2816	8.449	182.5
6 Lower Arm	R6	0.0116	30.00	0.100	BBL	BBL	3000.0
7 Crotch	R7	0.0116	30.00	0.360	0.6639	19.918	77.4
8 Thigh	R8	0.0116	30.00	0.063	BBL	BBL	3000.0
9 Lower Leg	R9	0.0116	30.00	0.170	0.1198	3.595	428.9
10 Neck	R10	0.0116	30.00	0.311	0.5228	15.683	98.3

Subject 2: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	R13	0.0116	30.00	0.156	0.0786	2.358	653.9
1 Back	R23	0.0116	30.00	0.071	BBL	BBL	3000.0
1 Back	R24	0.0116	30.00	0.060	BBL	BBL	3000.0
2 Chest	R14	0.0116	30.00	0.363	0.6711	20.133	76.6
3 Buttocks	R15	0.0116	30.00	0.185	0.1612	4.837	318.8
4 Axilla	R16	0.0116	30.00	0.187	0.1665	4.996	308.7
5 Upper Arm	R17	0.0116	30.00	0.237	0.3109	9.326	165.4
6 Lower Arm	R18	0.0116	30.00	0.098	BBL	BBL	3000.0
7 Crotch	R19	0.0116	30.00	0.222	0.2665	7.994	192.9
8 Thigh	R20	0.0116	30.00	0.127	BBL	BBL	3000.0
9 Lower Leg	R21	0.0116	30.00	0.044	BBL	BBL	3000.0
10 Neck	R22	0.0116	30.00	0.973	2.4197	72.590	21.2
Patch BK	T4	0.018	90.00	0.098	0.0607		
Patch BK	T5	0.018	90.00	0.159	0.0978		
			Avg:	0.12845			

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m³)
	30	1542	51.35

Responder Test 5, 23 Jun 95

Skin Area Region	Subject 1 Values Responder PF	A (D*PF)	Localized MRED mg-min/m³	Subject 2 Values BDO PF	A (D*PF)	Localized MRED mg-min/m³
1 **Chin & Neck**	98	5.7	12684	21	26.2	**2740**
2 Ears	98	1.1	16125	21	5.1	3484
3 Cheeks & Neck	98	2.1	16813	21	9.8	3632
4 Nape	98	0.6	60370	21	2.7	13043
5 Scalp	98	4.7	26646	21	21.7	5757
6 Abdomen	279	4.6	222416	193	6.7	153332
7 Back	1530	0.6	1447173	1263	0.8	1195093
8 Buttocks	125	1.8	190844	319	0.7	484907
9 Arms (lower, volar)	3000	0.1	3000000	3000	0.1	3000000
10 Arms (upper, volar)	183	1.0	182500	165	1.1	165351
11 Elbows (back)	183	0.1	146730	165	0.1	132942
12 Arms (lower, dorsum)	3000	0.0	7038000	3000	0.0	7038000
13 Arms (upper, dorsum)	183	0.6	428145	165	0.6	387914
14 Legs (plantar, lower)	429	0.8	428886	3000	0.1	3000000
15 Legs (plantar, upper)	3000	0.1	4563000	3000	0.1	4563000
16 Legs (dorsum, lower)	429	0.7	1006167	3000	0.1	7038000
17 Legs (dorsum, upper)	3000	0.1	7038000	3000	0.1	7038000
18 Knees (front)	429	0.1	1093659	3000	0.0	7650000
19 **Scrotum**	77	23.5	**3019**	193	9.4	7523
20 Groin	77	3.2	33753	193	1.3	84102
21 Axillae	60	1.6	44016	309	0.3	228104
22 Popliteal Space	429	0.1	319949	3000	0.0	2238000
23 Elbowfold	3000	0.0	2238000	3000	0.0	2238000
		53.1			87.1	
Overall PF:	**152.5**			**93.0**		
Systemic MRED:	**1524.7**			**929.9**		

Responder Suit Protection Factor Test 6 26 June 95

Subject 1: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	N2-R	0.0116	30.00	0.172	BBL	BBL	3000.0
1 Back	N15	0.0116	30.00	0.151	BBL	BBL	3000.0
1 Back	C3-R	0.0116	30.00	0.111	BBL	BBL	3000.0
2 Chest	N3	0.0116	30.00	1.126	2.0815	62.444	26.2
3 Buttocks	N4	0.0116	30.00	0.107	BBL	BBL	3000.0
4 Axilla	N5	0.0116	30.00	0.258	BBL	BBL	3000.0
5 Upper Arm	N8	0.0116	30.00	0.279	BBL	BBL	3000.0
6 Lower Arm	N9	0.0116	30.00	0.141	BBL	BBL	3000.0
7 Crotch	N10	0.0116	30.00	1.738	3.8355	115.064	14.2
8 Thigh	N11-L	0.0116	30.00	0.139	BBL	BBL	3000.0
9 Lower Leg	N13	0.0116	30.00	0.431	0.0921	2.762	593.3
10 Neck	N14	0.0116	30.00	2.541	6.1350	184.051	8.9

Subject 2: Responder, taped with bootie

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	CH1	0.0116	30.00	0.763	1.0431	31.293	52.4
1 Back	CH13	0.0116	30.00	0.596	0.5651	16.954	96.7
1 Back	CH14-R	0.0116	30.00	0.240	BBL	BBL	3000.0
2 Chest	CH2	0.0116	30.00	0.362	BBL	BBL	3000.0
3 Buttocks	CH3	0.0116	30.00	0.182	BBL	BBL	3000.0
4 Axilla	CH5	0.0116	30.00	0.107	BBL	BBL	3000.0
5 Upper Arm	CH6	0.0116	30.00	0.462	0.1808	5.425	302.1
6 Lower Arm	CH7	0.0116	30.00	0.224	BBL	BBL	3000.0
7 Crotch	CH8	0.0116	30.00	1.248	2.4323	72.968	22.5
8 Thigh	CH9	0.0116	30.00	0.099	BBL	BBL	3000.0
9 Lower Leg	CH11	0.0116	30.00	0.145	BBL	BBL	3000.0
10 Neck	CH12	0.0116	30.00	0.271	BBL	BBL	3000.0

Patch BK	X4	0.018	90.00	0.597	0.3687
Patch BK	X5	0.018	90.00	0.201	0.1240
			Avg:	0.39905	

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m^3)
	30	1638.8	51.21

Pos Control	C1	0.018	30.00	24.627	45.60
Pos Control	C2	0.018	30.00	25.346	46.94
			Avg:	24.986	46.27

Responder Suit Protection Factor Test 6 26 June 95

Subject 3: Responder, taped with bootie

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	H1	0.0116	30.00	0.151	BBL	BBL	3000.0
1 Back	H10	0.0116	30.00	0.080	BBL	BBL	3000.0
1 Back	H11	0.0116	30.00	0.281	BBL	BBL	3000.0
2 Chest	H2-L-R	0.0116	30.00	0.106	BBL	BBL	3000.0
3 Buttocks	H3	0.0116	30.00	0.158	BBL	BBL	3000.0
4 Axilla	H4	0.0116	30.00	1.077	1.9400	58.200	28.2
5 Upper Arm	H4A	0.0116	30.00	0.053	BBL	BBL	3000.0
6 Lower Arm	H5	0.0116	30.00	0.854	1.3034	39.102	41.9
7 Crotch	H5A	0.0116	30.00	0.194	BBL	BBL	3000.0
8 Thigh	H7	0.0116	30.00	0.343	BBL	BBL	3000.0
9 Lower Leg	H8	0.0116	30.00	0.060	BBL	BBL	3000.0
10 Neck	H9	0.0116	30.00	0.507	0.3077	9.231	177.5

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m^3)
	30	1638.8	51.21

Responder Test 6, 26 Jun 95

	Subject 1 Values BDO			Subject 2 Values Responder, taped with bootie		
Skin Area Region	PF	A (D*PF)	Localized MRED mg-min/m^3	PF	A (D*PF)	Localized MRED mg-min/m^3
1 Chin & Neck	9	62.4	1149	3000	0.2	387000
2 Ears	9	12.2	1460	3000	0.0	492000
3 Cheeks & Neck	9	23.4	1523	3000	0.1	513000
4 Nape	9	6.5	5467	3000	0.0	1842000
5 Scalp	9	51.7	2413	3000	0.2	813000
6 Abdomen	1513	0.8	1204445	3000	0.4	2388000
7 Back	3000	0.3	2838000	2025	0.5	1915497
8 Buttocks	3000	0.1	4563000	3000	0.1	4563000
9 Arms (lower, volar)	3000	0.1	3000000	3000	0.1	3000000
10 Arms (upper, volar)	3000	0.1	3000000	302	0.6	302069
11 Elbows (back)	3000	0.0	2412000	302	0.1	242863
12 Arms (lower, dorsum)	3000	0.0	7038000	3000	0.0	7038000
13 Arms (upper, dorsum)	3000	0.0	7038000	302	0.4	708653
14 Legs (plantar, lower)	593	0.6	593332	3000	0.1	3000000
15 Legs (plantar, upper)	3000	0.1	4563000	3000	0.1	4563000
16 Legs (dorsum, lower)	593	0.5	1391957	3000	0.1	7038000
17 Legs (dorsum, upper)	3000	0.1	7038000	3000	0.1	7038000
18 Knees (front)	593	0.0	1512997	3000	0.0	7650000
19 **Scrotum**	14	127.7	**555**	22	81.0	**876**
20 Groin	14	17.3	6210	22	10.9	9792
21 Axillae	3000	0.0	2217000	3000	0.0	2217000
22 Popliteal Space	593	0.1	442626	3000	0.0	2238000
23 Elbowfold	3000	0.0	2238000	3000	0.0	2238000
		304.1			95.0	
Overall PF:	**26.6**			**85.2**		
Systemic MRED:	**266.2**			**852.3**		

Responder Test 6, 26 Jun 95

Subject 3 Values
Responder, taped with bootie

Skin Area Region	PF	A (D*PF)	Localized MRED mg-min/m^3
1 Chin & Neck	178	3.1	22901
2 Ears	178	0.6	29115
3 Cheeks & Neck	178	1.2	30358
4 Nape	178	0.3	109004
5 Scalp	178	2.6	48111
6 Abdomen	1514	0.8	1205207
7 Back	1514	0.6	1432319
8 Buttocks	3000	0.1	4563000
9 Arms (lower, volar)	42	4.1	41911
10 Arms (upper, volar)	3000	0.1	3000000
11 Elbows (back)	3000	0.0	2412000
12 Arms (lower, dorsum)	42	2.6	98322
13 Arms (upper, dorsum)	3000	0.0	7038000
14 Legs (plantar, lower)	3000	0.1	3000000
15 Legs (plantar, upper)	3000	0.1	4563000
16 Legs (dorsum, lower)	3000	0.1	7038000
17 Legs (dorsum, upper)	3000	0.1	7038000
18 Knees (front)	3000	0.0	7650000
19 Scrotum	3000	0.6	117000
20 Groin	3000	0.1	1308000
21 **Axillae**	28	3.4	**20809**
22 Popliteal Space	3000	0.0	2238000
23 Elbowfold	42	0.6	31265
		21.4	

Overall PF: **378.5**

Systemic MRED: **3785.2**

Responder Suit Protection Factor Test 7 27 June 95

Subject 1: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	5	0.0116	30.00	0.751	1.9068	57.204	29.1
1 Back	H18	0.0116	30.00	2.975	8.2762	248.286	6.7
1 Back	H19	0.0116	30.00	0.680	1.7035	51.104	32.5
2 Chest	6	0.0116	30.00	0.249	0.4689	14.068	118.2
3 Buttocks	7	0.0116	30.00	0.071	BBL	BBL	3000.0
4 Axilla	H10	0.0116	30.00	0.695	1.7458	52.375	31.8
5 Upper Arm	H11	0.0116	30.00	0.183	0.2796	8.389	198.3
6 Lower Arm	H12	0.0116	30.00	0.582	1.4220	42.659	39.0
7 Crotch	H14-L	0.0116	30.00	0.290	0.5846	17.539	94.8
8 Thigh	H15	0.0116	30.00	2.087	5.7330	171.989	9.7
9 Lower Leg	H16	0.0116	30.00	5.692	16.0560	481.680	3.5
10 Neck	H17	0.0116	30.00	0.468	1.0946	32.839	50.7

Subject 2: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	C5	0.0116	30.00	0.071	BBL	BBL	3000.0
1 Back	CA6	0.0116	30.00	0.322	0.6774	20.322	81.9
1 Back	CA7	0.0116	30.00	0.231	0.4174	12.521	132.8
2 Chest	C8	0.0116	30.00	0.269	0.5268	15.803	105.3
3 Buttocks	C9	0.0116	30.00	0.229	0.4125	12.375	134.4
4 Axilla	C10	0.0116	30.00	0.084	BBL	BBL	3000.0
5 Upper Arm	C11	0.0116	30.00	0.218	0.3804	11.413	145.7
6 Lower Arm	C12	0.0116	30.00	0.491	1.1602	34.807	47.8
7 Crotch	C13	0.0116	30.00	0.355	0.7722	23.166	71.8
8 Thigh	C14	0.0116	30.00	0.051	BBL	BBL	3000.0
9 Lower Leg	C15	0.0116	30.00	0.636	1.5772	47.315	35.2
10 Neck	C16	0.0116	30.00	10.860	30.8547	925.640	1.8

Patch BK	1	0.018	90.00	0.099	0.0610
Patch BK	2	0.018	90.00	0.072	0.0444
			Avg:	0.08535	

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m^3)
	30	1663.4	51.98

Pos Control	R5	0.018	30.00	23.977	44.40
Pos Control	R6	0.018	30.00	25.346	46.94
			Avg:	24.661	45.67

Responder Suit Protection Factor Test 7 27 June 95

Subject 3: Responder with bootie

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	T5	0.0116	30.00	0.066	BBL	BBL	3000.0
1 Back	R21	0.0116	30.00	1.954	5.3521	160.563	10.4
1 Back	R23	0.0116	30.00	1.316	3.5242	105.726	15.7
2 Chest	R7	0.0116	30.00	0.069	BBL	BBL	3000.0
3 Buttocks	R8	0.0116	30.00	0.131	0.1310	3.930	423.2
4 Axilla	R10	0.0116	30.00	0.037	BBL	BBL	3000.0
5 Upper Arm	R11	0.0116	30.00	2.626	7.2768	218.303	7.6
6 Lower Arm	R12	0.0116	30.00	0.166	0.2310	6.929	240.1
7 Crotch	R14	0.0116	30.00	0.215	0.3716	11.147	149.2
8 Thigh	R16	0.0116	30.00	0.053	BBL	BBL	3000.0
9 Lower Leg	R17	0.0116	30.00	0.493	1.1685	35.056	47.5
10 Neck	R18	0.0116	30.00	0.673	1.6840	50.520	32.9

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m^3)
	30	1663.4	51.98

Responder Test 7, 27 Jun 95

Skin Area Region	Subject 1 Values Responder PF	A (D*PF)	Localized MRED mg-min/m³	Subject 2 Values BDO PF	A (D*PF)	Localized MRED mg-min/m³
1 **Chin & Neck**	51	11.0	6534	2	309.2	**232**
2 Ears	51	2.1	8307	2	60.5	295
3 Cheeks & Neck	51	4.1	8662	2	115.9	307
4 Nape	51	1.1	31101	2	32.4	1103
5 Scalp	51	9.1	13727	2	256.3	487
6 Abdomen	75	17.1	59700	1553	0.8	1235892
7 Back	27	35.2	25795	2036	0.5	1925850
8 Buttocks	3000	0.1	4563000	134	1.7	204440
9 Arms (lower, volar)	39	4.5	38993	48	3.6	47790
10 Arms (upper, volar)	198	0.9	198279	146	1.2	145743
11 Elbows (back)	198	0.1	159417	146	0.2	117177
12 Arms (lower, dorsum)	39	2.8	91478	48	2.2	112115
13 Arms (upper, dorsum)	198	0.5	465163	146	0.7	341913
14 Legs (plantar, lower)	3	98.0	3453	35	9.6	35156
15 Legs (plantar, upper)	10	34.5	14710	3000	0.1	4563000
16 Legs (dorsum, lower)	3	83.6	8102	35	8.2	82475
17 Legs (dorsum, upper)	10	44.8	22689	3000	0.1	7038000
18 Knees (front)	3	8.1	8806	35	0.8	89647
19 Scrotum	95	19.2	3699	72	25.3	2800
20 Groin	95	2.6	41351	72	3.4	31307
21 Axillae	32	3.0	23470	3000	0.0	2217000
22 **Popliteal Space**	3	13.9	**2576**	35	1.4	26226
23 Elbowfold	39	0.6	29089	48	0.5	35651
		396.9			834.7	
Overall PF:	**20.4**			**9.7**		
Systemic MRED:	**204.0**			**97.0**		

Responder Test 7, 27 Jun 95

Subject 3 Values
Responder with bootie

Skin Area Region	PF	A (D*PF)	Localized MRED mg-min/m3
1 **Chin & Neck**	33	16.9	**4247**
2 Ears	33	3.3	5400
3 Cheeks & Neck	33	6.3	5630
4 Nape	33	1.8	20216
5 Scalp	33	14.0	8923
6 Abdomen	3000	0.4	2388000
7 Back	2004	0.5	1896114
8 Buttocks	423	0.5	643706
9 Arms (lower, volar)	240	0.7	240074
10 Arms (upper, volar)	8	22.9	7620
11 Elbows (back)	8	2.9	6126
12 Arms (lower, dorsum)	240	0.4	563214
13 Arms (upper, dorsum)	8	14.1	17876
14 Legs (plantar, lower)	47	7.1	47450
15 Legs (plantar, upper)	3000	0.1	4563000
16 Legs (dorsum, lower)	47	6.1	111318
17 Legs (dorsum, upper)	3000	0.1	7038000
18 Knees (front)	47	0.6	120998
19 Scrotum	149	12.2	5820
20 Groin	149	1.6	65062
21 Axillae	3000	0.0	2217000
22 Popliteal Space	47	1.0	35398
23 Elbowfold	240	0.1	179095
		113.8	

Overall PF: **71.1**

Systemic MRED: **711.4**

Responder Suit Protection Factor Test 8 28 June 95

Subject 1: Responder, taped with bootie

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	CH1	0.0116	30.00	0.076	0.0285	0.855	1843.2
1 Back	CH14	0.0116	30.00	2.261	6.2857	188.570	8.4
1 Back	X4	0.0116	30.00	0.162	0.2748	8.243	191.1
2 Chest	CH2	0.0116	30.00	0.361	0.8441	25.322	62.2
3 Buttocks	CH3	0.0116	30.00	0.255	0.5402	16.207	97.2
4 Axilla	CH5	0.0116	30.00	0.203	0.3922	11.765	133.9
5 Upper Arm	CH7	0.0116	30.00	0.257	0.5471	16.413	96.0
6 Lower Arm	CH8	0.0116	30.00	0.175	0.3106	9.317	169.1
7 Crotch	CH9	0.0116	30.00	0.074	0.0228	0.683	2306.9
8 Thigh	CH11	0.0116	30.00	0.414	0.9958	29.875	52.7
9 Lower Leg	CH12	0.0116	30.00	0.073	0.0205	0.614	2565.0
10 Neck	CH13	0.0116	30.00	0.053	BBL	BBL	3000.0

Subject 2: Responder, taped with bootie

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m³)	Dosage mg-min/m³	PF
1 Back	ST11	0.0116	30.00	0.459	1.1250	33.750	46.7
1 Back	C2	0.0116	30.00	0.133	0.1929	5.786	272.3
1 Back	C3	0.0116	30.00	0.253	0.5354	16.061	98.1
2 Chest	H3	0.0116	30.00	0.056	BBL	BBL	3000.0
3 Buttocks	H4	0.0116	30.00	0.223	0.4495	13.484	116.9
4 Axilla	H5	0.0116	30.00	0.050	BBL	BBL	3000.0
5 Upper Arm	H7	0.0116	30.00	0.819	2.1548	64.643	24.4
6 Lower Arm	H8	0.0116	30.00	0.063	BBL	BBL	3000.0
7 Crotch	H9	0.0116	30.00	0.232	0.4752	14.257	110.5
8 Thigh	H10	0.0116	30.00	0.697	1.8080	54.240	29.0
9 Lower Leg	H11	0.0116	30.00	0.693	1.7960	53.879	29.2
10 Neck	C1	0.0116	30.00	0.224	0.4517	13.552	116.3
Patch BK	H1	0.018	90.00	0.065	0.0399		
Patch BK	ST2	0.018	90.00	0.068	0.0417		
			Avg:	0.06605			

Data Acquisition System	# Mins	Dosage	Avg Conc
	30	1575.6	50.83

Pos Control	ST4	0.018	30.00	24.304	45.01	
Pos Control	ST5	0.018	30.00	20.344	37.67	
			Avg:	22.324	41.34	

Responder Suit Protection Factor Test 8 28 June 95

Subject 3: Responder, taped with bootie

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	3	0.0116	30.00	0.131	0.1863	5.588	281.9
1 Back	B3	0.0116	30.00	0.215	0.4260	12.779	123.3
1 Back	B4	0.0116	30.00	0.066	BBL	BBL	3000.0
2 Chest	4	0.0116	30.00	1.070	2.8741	86.224	18.3
3 Buttocks	R1	0.0116	30.00	0.054	BBL	BBL	3000.0
4 Axilla	R2	0.0116	30.00	0.151	0.2433	7.298	215.9
5 Upper Arm	R4	0.0116	30.00	0.104	0.1078	3.235	487.1
6 Lower Arm	R15	0.0116	30.00	0.226	0.4575	13.724	114.8
7 Crotch	R19	0.0116	30.00	0.082	0.0457	1.370	1149.8
8 Thigh	R20	0.0116	30.00	0.094	0.0792	2.375	663.3
9 Lower Leg	R22	0.0116	30.00	0.179	0.3235	9.704	162.4
10 Neck	R24	0.0116	30.00	0.116	0.1430	4.291	367.2

Subject 4: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	A1-L	0.0116	30.00	0.049	BBL	BBL	3000.0
1 Back	CA4	0.0116	30.00	0.153	0.2501	7.504	210.0
1 Back	CA8	0.0116	30.00	0.068	0.0042	0.125	12648.3
2 Chest	A2	0.0116	30.00	1.868	5.1591	154.772	10.2
3 Buttocks	A4	0.0116	30.00	0.106	0.1144	3.432	459.1
4 Axilla	AA4	0.0116	30.00	0.070	0.0102	0.305	5166.2
5 Upper Arm	A5	0.0116	30.00	1.883	5.2032	156.095	10.1
6 Lower Arm	A6	0.0116	30.00	0.898	2.3824	71.473	22.0
7 Crotch	A7	0.0116	30.00	0.198	0.3779	11.336	139.0
8 Thigh	A8	0.0116	30.00	0.718	1.8681	56.044	28.1
9 Lower Leg	A9	0.0116	30.00	0.066	BBL	BBL	3000.0
10 Neck	A10	0.0116	30.00	0.032	BBL	BBL	3000.0

Data Acquisition System	# Mins	Dosage	Avg Conc (mg/m^3)
	30.00	1575.60	50.83

Responder Test 8, 28 Jun 95

Skin Area Region	Subject 1 Values Responder, taped w/bootie PF	A (D*PF)	Localized MRED mg-min/m³	Subject 2 Values Responder, taped w/bootie PF	A (D*PF)	Localized MRED mg-min/m³
1 Chin & Neck	3000	0.2	387000	116	4.8	14998
2 Ears	3000	0.0	492000	116	0.9	19067
3 Cheeks & Neck	3000	0.1	513000	116	1.8	19880
4 Nape	3000	0.0	1842000	116	0.5	71384
5 Scalp	3000	0.2	813000	116	4.0	31506
6 Abdomen	98	13.1	78064	3000	0.4	2388000
7 Back	407	2.4	385410	1570	0.6	1484762
8 Buttocks	97	2.3	147867	117	1.9	177732
9 Arms (lower, volar)	169	1.0	169110	3000	0.1	3000000
10 Arms (upper, volar)	96	1.8	95996	24	7.2	24374
11 **Elbows (back)**	96	0.2	**77181**	24	0.9	19596
12 Arms (lower, dorsum)	169	0.6	396732	3000	0.0	7038000
13 Arms (upper, dorsum)	96	1.1	225206	24	4.4	57181
14 Legs (plantar, lower)	2565	0.1	2565033	29	11.6	29243
15 Legs (plantar, upper)	53	6.3	80216	29	11.5	44183
16 Legs (dorsum, lower)	2565	0.1	6017567	29	9.9	68605
17 Legs (dorsum, upper)	53	8.2	123726	29	14.9	68149
18 Knees (front)	2565	0.0	6540833	29	1.0	74571
19 **Scrotum**	2307	0.8	89970	111	16.5	**4310**
20 Groin	2307	0.1	1005815	111	2.2	48185
21 Axillae	134	0.7	98965	3000	0.0	2217000
22 Popliteal Space	2565	0.0	1913514	29	1.6	21816
23 Elbowfold	169	0.1	126156	3000	0.0	2238000
		39.6			96.6	
Overall PF:	**204.5**			**83.8**		
Systemic MRED:	**2044.8**			**837.6**		

Responder Test 8, 28 Jun 95

Skin Area Region	Subject 3 Values Responder, taped w/bootie PF	A (D*PF)	Localized MRED mg-min/m^3	Subject 4 Values BDO PF	A (D*PF)	Localized MRED mg-min/m^3
1 Chin & Neck	367	1.5	47365	3000	0.2	387000
2 Ears	367	0.3	60215	3000	0.0	492000
3 Cheeks & Neck	367	0.6	62786	3000	0.1	513000
4 Nape	367	0.2	225440	3000	0.0	1842000
5 Scalp	367	1.3	99502	3000	0.2	813000
6 Abdomen	117	10.9	93198	2588	0.5	2060196
7 Back	675	1.4	639008	5226	0.2	4943923
8 Buttocks	3000	0.1	4563000	459	0.5	698251
9 Arms (lower, volar)	115	1.5	114804	22	7.9	22045
10 Arms (upper, volar)	487	0.4	487118	10	17.3	10094
11 Elbows (back)	487	0.0	391643	10	2.2	8115
12 Arms (lower, dorsum)	115	0.9	269331	22	4.9	51717
13 Arms (upper, dorsum)	487	0.2	1142778	10	10.6	23680
14 Legs (plantar, lower)	162	2.1	162373	3000	0.1	3000000
15 Legs (plantar, upper)	663	0.5	1008865	28	11.9	42761
16 Legs (dorsum, lower)	162	1.8	380926	3000	0.1	7038000
17 Legs (dorsum, upper)	663	0.7	1556080	28	15.4	65955
18 Knees (front)	162	0.2	414050	3000	0.0	7650000
19 **Scrotum**	1150	1.6	**44844**	139	13.1	**5421**
20 Groin	1150	0.2	501331	139	1.8	60600
21 Axillae	216	0.4	159544	5166	0.0	3817816
22 Popliteal Space	162	0.3	121130	3000	0.0	2238000
23 Elbowfold	115	0.2	85644	22	1.1	16445
		27.2			88.0	
Overall PF:	**297.2**			**92.0**		
Systemic MRED:	**2971.6**			**920.2**		

Responder Suit Protection Factor Test 9 30 June 95

Subject 1: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	R1	0.0116	30.00	0.172	0.1201	3.604	451.7
1 Back	R11	0.0116	30.00	0.182	0.1468	4.403	369.7
1 Back	R12	0.0116	30.00	0.734	1.7287	51.860	31.4
2 Chest	R2	0.0116	30.00	0.060	BBL	BBL	3000.0
3 Buttocks	R3	0.0116	30.00	0.061	BBL	BBL	3000.0
4 Axilla	R4	0.0116	30.00	0.129	BBL	BBL	3000.0
5 Upper Arm	R5	0.0116	30.00	0.237	0.3048	9.145	178.0
6 Lower Arm	R6	0.0116	30.00	0.415	0.8140	24.420	66.7
7 Crotch	R7	0.0116	30.00	0.079	BBL	BBL	3000.0
8 Thigh	R8	0.0116	30.00	0.217	0.2467	7.401	219.9
9 Lower Leg	R9	0.0116	30.00	2.118	5.6920	170.760	9.5
10 Neck	R10	0.0116	30.00	0.077	BBL	BBL	3000.0

Subject 2: Responder

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (µg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	R13	0.0116	30.00	0.065	BBL	BBL	3000.0
1 Back	CH12	0.0116	30.00	2.093	5.6201	168.604	9.7
1 Back	SH8	0.0116	30.00	0.159	0.0826	2.479	656.8
2 Chest	R14	0.0116	30.00	0.260	0.3718	11.155	145.9
3 Buttocks	R15	0.0116	30.00	0.176	0.1302	3.905	416.9
4 Axilla	R16	0.0116	30.00	0.709	1.6574	49.721	32.7
5 Upper Arm	R17	0.0116	30.00	0.381	0.7161	21.482	75.8
6 Lower Arm	R18	0.0116	30.00	0.514	1.0981	32.942	49.4
7 Crotch	R19	0.0116	30.00	0.161	0.0863	2.590	628.4
8 Thigh	R20	0.0116	30.00	0.880	2.1468	64.403	25.3
9 Lower Leg	R21	0.0116	30.00	2.544	6.9125	207.375	7.8
10 Neck	R23	0.0116	30.00	0.178	0.1365	4.094	397.6

Patch BK	T4	0.018	90.00	0.179	0.1106
Patch BK	ST1	0.018	90.00	0.082	0.0505
			Avg:	0.13045	

Data Acquisition System	# Mins	Dosage	Avg Conc
	30	1627.8	50.11

Pos Control	ST4	0.018	30.00	24.304	45.01
Pos Control	ST5	0.018	30.00	20.344	37.67
			Avg:	22.324	41.34

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Subject 3: BDO

Sample Location	Tube	Flow (L/min)	Total (min)	Mass (μg)	MS Conc (mg/m^3)	Dosage $mg\text{-}min/m^3$	PF
1 Back	N2	0.0116	30.00	0.151	0.0597	1.791	908.8
1 Back	CH22	0.0116	30.00	0.087	BBL	BBL	3000.0
1 Back	HL2	0.0116	30.00	0.129	BBL	BBL	3000.0
2 Chest	N3	0.0116	30.00	0.117	BBL	BBL	3000.0
3 Buttocks	N4	0.0116	30.00	1.523	3.9884	119.652	13.6
4 Axilla	N8	0.0116	30.00	0.121	BBL	BBL	3000.0
5 Upper Arm	N9	0.0116	30.00	0.055	BBL	BBL	3000.0
6 Lower Arm	N10	0.0116	30.00	0.047	BBL	BBL	3000.0
7 Crotch	N13	0.0116	30.00	0.369	0.6823	20.468	79.5
8 Thigh	N14	0.0116	30.00	0.063	BBL	BBL	3000.0
9 Lower Leg	N15	0.0116	30.00	0.209	0.2252	6.757	240.9
10 Neck	N16	0.0116	30.00	2.630	7.1568	214.704	7.6
Patch BK	T4	0.018	90.00	0.179	0.1106		
Patch BK	ST1	0.018	90.00	0.082	0.0505		
			Avg:	0.1305			

Data Acquisition System	# Mins	Dosage	Avg Conc
	30	1627.8	50.11

Responder Test 9, 30 Jun 95

Skin Area Region	Subject 1 Values Responder PF	A (D*PF)	Localized MRED mg-min/m^3	Subject 2 Values Responder PF	A (D*PF)	Localized MRED mg-min/m^3
1 Chin & Neck	3000	0.2	387000	398	1.4	51296
2 Ears	3000	0.0	492000	398	0.3	65213
3 Cheeks & Neck	3000	0.1	513000	398	0.5	67997
4 Nape	3000	0.0	1842000	398	0.1	244152
5 Scalp	3000	0.2	813000	398	1.2	107761
6 Abdomen	3000	0.4	2388000	89	14.3	71106
7 Back	1642	0.6	1553453	627	1.5	593557
8 Buttocks	3000	0.1	4563000	417	0.5	634088
9 Arms (lower, volar)	67	2.6	66658	49	3.5	49413
10 Arms (upper, volar)	178	1.0	177995	76	2.3	75775
11 Elbows (back)	178	0.1	143108	76	0.3	60923
12 Arms (lower, dorsum)	67	1.6	156380	49	2.2	115924
13 Arms (upper, dorsum)	178	0.6	417577	76	1.4	177769
14 Legs (plantar, lower)	10	35.5	9533	8	43.1	7850
15 Legs (plantar, upper)	220	1.5	334525	25	13.2	38444
16 Legs (dorsum, lower)	10	30.3	22364	8	36.8	18415
17 Legs (dorsum, upper)	220	2.0	515973	25	17.1	59296
18 Knees (front)	10	2.9	24308	8	3.6	20016
19 Scrotum	3000	0.6	117000	628	2.9	24509
20 Groin	3000	0.1	1308000	628	0.4	274002
21 Axillae	3000	0.0	2217000	33	3.0	24194
22 **Popliteal Space**	10	5.0	**7111**	8	6.1	**5856**
23 Elbowfold	67	0.4	49727	49	0.5	36862
		85.8			156.3	
Overall PF:	**94.3**			**51.8**		
Systemic MRED:	**943.4**			**518.1**		

Responder Test 9, 30 Jun 95

Subject 3 Values
BDO

Skin Area Region	PF	A (D*PF)	Localized MRED mg-min/m^3
1 **Chin & Neck**	8	73.3	**978**
2 Ears	8	14.3	1243
3 Cheeks & Neck	8	27.5	1296
4 Nape	8	7.7	4655
5 Scalp	8	60.7	2055
6 Abdomen	3000	0.4	2388000
7 Back	2651	0.4	2508281
8 Buttocks	14	16.4	20692
9 Arms (lower, volar)	3000	0.1	3000000
10 Arms (upper, volar)	3000	0.1	3000000
11 Elbows (back)	3000	0.0	2412000
12 Arms (lower, dorsum)	3000	0.0	7038000
13 Arms (upper, dorsum)	3000	0.0	7038000
14 Legs (plantar, lower)	241	1.4	240910
15 Legs (plantar, upper)	3000	0.1	4563000
16 Legs (dorsum, lower)	241	1.2	565175
17 Legs (dorsum, upper)	3000	0.1	7038000
18 Knees (front)	241	0.1	614321
19 Scrotum	80	22.9	3102
20 Groin	80	3.1	34674
21 Axillae	3000	0.0	2217000
22 Popliteal Space	241	0.2	179719
23 Elbowfold	3000	0.0	2238000
	230.1		

Overall PF: **35.2**

Systemic MRED: **351.8**

DOCUMENT 4

Potential Values of a Simple BW Protective Mask

AD-A302 657

September 1995

Institute for Defense Analyses
Alexandria, VA

Copy 103

IDA PAPER P-3077

POTENTIAL VALUES OF A SIMPLE BW PROTECTIVE MASK

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Graham Pearson (CBDE)
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September 1995

Prepared for
Office of the Under Secretary of Defense for Policy
International Security Policy

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CHEMICAL & BIOLOGICAL DEFENCE ESTABLISHMENT
Porton Down, Salisbury, Wilts. SP4 0JQ

IDA Log No. HQ 95-47254

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1995	Final

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Potential Values of a Simple BW Protective Mask	C-DASWO1-94-C-0054 T-K6-1263
6. AUTHOR(s) Karl Lowe, Victor Utgoff, Graham Pearson	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 1801 N. Beauregard Street Alexandria, VA 22311	8. PERFORMING ORGANIZATION REPORT NUMBER IDA P-3077
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of the Under Secretary of Defense for Policy International Security Policy/Policy Planning The Pentagon, Rm. 1C477 Washington, DC 20301	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This paper argues that a relatively simple oro-nasal mask is the key to effective protection against large-scale biological weapon attacks. To show the efficacy of such a mask, this paper compares the threat posed by the three classes of weapons of mass destruction: nuclear, biological, and chemical. This comparison demonstrates that: a) for unprotected population the biological weapons threat may be even greater than that presented by nuclear weapons, whereas, b) for populations protected by the oro-nasal mask, the biological threat may be made several orders of magnitude less than that of nuclear weapons.

14. SUBJECT TERMS	15. NUMBER OF PAGES
biological warfare, chemical warfare, nuclear warfare, weapons of mass destruction, civil defense, protective masks, NBC threats	24
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

IDA PAPER P-3077

POTENTIAL VALUES OF A SIMPLE BW PROTECTIVE MASK

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Victor Utgoff (IDA)

September 1995

INSTITUTE FOR DEFENSE ANALYSES
CHEMICAL & BIOLOGICAL DEFENCE ESTABLISHMENT

Contract DASW01 94 C 0054
Task T-K6-1263

PREFACE

This paper was prepared in support of IDA's task entitled "Biological Warfare Defense Issues" sponsored by the Office of the Assistant Secretary of Defense for International Security Policy. Technical oversight of the study for the U.S. DoD was carried out by Ms. Lisa Bronson, Director of Negotiations and Implementations, and Mr. Paul Gebhard, Director of Policy Planning and Regional Security, both of the Office of the Deputy Assistant Secretary for Counterproliferation Policy.

This collaboration between U.S. and U.K. organizations was arranged informally by the authors. The pooling of information and the somewhat different perspectives on the issues involved allowed a better product than either organization could have created alone with equivalent total effort. We hope that others will be encouraged to create similar cooperative international arrangements for studying problems of mutual interest.

The authors greatly appreciate the helpful comments and assistance received during the development of this paper. Reviewers include Richard Aiken, John Bartlett, Lisa Bronson, Seth Carus, Marty Crumrine, Richard Danzig, Tom Dashiell, Paul Gebhard, Andy Hull, Chris Jehn, Barbara Johnson, Robert Kadlec, Edward Kerlin, Joshua Lederberg, William Patrick III, Brad Roberts, Douglas Schultz, Bernard Tucker, and Chris Whalley. Jeff Preston and Craig Colton of the 3M Company, and Michael Fuchs of UVEX, were helpful in obtaining information and samples of potentially suitable BW masks. Johnathan Wallis was most helpful in researching key background information and performing repeated calculations.

Finally, the authors note that the opinions expressed in this paper are their own, and are not necessarily endorsed by the organizations with which they are or have been affiliated.

CONTENTS

EXECUTIVE SUMMARY

The Persian Gulf War heightened awareness of the potential threat posed by biological weapons to our armed forces, and to the forces and civilian populations of allies. It reminded defense officials that BW could produce casualties comparable in number to those possible with nuclear weapons. The prospect of such high losses could lead regional governments to refuse to join us in defending important common interests.

This paper argues that a relatively simple oro-nasal mask is the key to effective protection against large-scale BW attack. To show the efficacy of such a mask, this paper compares the threat posed by the three classes of weapons of mass destruction: nuclear, biological, and chemical. This comparison demonstrates that for *unprotected* populations the threat of BW can be even greater than that posed by nuclear weapons, whereas for *protected* populations the BW threat can be made several orders of magnitude less than that posed by nuclear weapons.

Because less than ten kilograms of biological agent could devastate a target such as an unprotected city, the prospects of interdicting biological attacks before they can be delivered are poor. Similarly, while both pre- and post-exposure medications can offer some protection against some BW agents, they cannot provide reliable protection against the full range of potential agents.

The primary BW threat is attack through inhalation, as BW attacks aimed at infecting victims through the digestive tract or skin are less effective and can be countered by normal sanitation measures. Recognizing this, the paper explores the protective potential of simple oro-nasal dust masks. Masks that can reduce the potential effectiveness of BW agents by a factor of as much as 10,000 are available commercially, for less than $5 each. By providing protection, such masks would require an attacker seeking to devastate concentrations of population to deliver far higher amounts of BW agent—and therefore to use readily observable means of delivery. This can enable good use of active protection measures, such as air and missile defenses, or preemptive attacks to destroy BW capabilities before they can be launched toward their targets. Other synergistic effects are possible. For example, even partial protection could still reduce the concentrations of BW agents reaching victims to levels where medical treatment and the body's natural defenses can be more effective.

A variety of practical problems must be solved to realize the full protective potential of simple BW masks. For example, greater variations in size and shape are needed to allow a reliable fit for entire populations. Instruction and training would be needed. BW sensors to warn of attack would be important to allow populations to remove their masks when it is safe to do so.

In sum, simple masks appear to have the potential to dramatically suppress the danger of BW attack. The authors recommend that an aggressive program be created now to develop and exploit this potential.

I. INTRODUCTION

Proliferation of nuclear, biological, and chemical (NBC) weapons is a growing concern. Unless the spread of these weapons can somehow be halted, major changes will be required in allied defense strategy and capabilities. The risks and costs of defending vital interests will rise substantially. Correspondingly, the US, the UK, and their allies will find defense of their important interests more difficult and painful, and other states will become far less willing to support such defense efforts. Recognizing this, the allies are aggressively searching for more effective political means to halt NBC proliferation, and, to the extent it cannot be halted, for military and technical means to counter it.

Clearly these pursuits complement each other. Political measures can complicate, slow, and deter proliferation and strengthen the basis for international reaction when evidence of prohibited programs appears. Thus, they should reduce the number and scope of the NBC weapons programs to be countered, buy time to deploy countermeasures, and win domestic and international political support for difficult counterproliferation actions. At the same time, better means of countering NBC weapons should decrease demand for them by reducing their political and military utilities.

The purpose of this paper is to provide a broad perspective on the value of simple BW masks, particularly for civilians. We will argue that such masks are an essential ingredient of any strategy for countering BW proliferation, that history shows that populations are willing to take such unusual measures as wearing protective masks when a frightening disease threatens, and that masks may have the potential to prevent BW from becoming an even greater strategic threat than that posed by nuclear weapons.

Civilians are the primary focus for several reasons. NATO troops, at least if warned, have individual CW physical protection that protects against BW attacks as well. The US, UK and their allies depend on civilians in overseas theaters to operate the ports, airbases, and infrastructure upon which intervention forces would depend. The vulnerability of civilian populations to BW attack, both at home and in overseas countries, could lead governments to hesitate to support interventions against a state assessed to have a BW capability. Nonetheless, we will discuss the more direct values of simple BW masks for military forces in section VIII, below.

II. COMPARING THE THREATS POSED BY NUCLEAR, CHEMICAL, AND BIOLOGICAL WEAPONS

Nuclear, biological, and chemical weapons all have been described as "weapons of mass destruction." However, these three classes of weapons have very different potentials for causing mass destruction, and, in this respect, their proliferation should not be of equal concern. The most important measure of the difference in their potential to cause mass destruction is the *"residual threat"* they each pose after all practical countermeasures have been taken.

Nuclear weapons pose a high residual threat because the prospects of achieving a near-perfect defense against nuclear attack at reasonable cost seem poor, and the detonation of even a single nuclear weapon on an allied city or major military force would cause enormous numbers of casualties and great destruction.

Chemical weapons pose a substantially smaller residual threat. When used against concentrations of unprotected military or civilian personnel, they require considerably more weight on target to inflict the same numbers of casualties as would a single nuclear-armed missile. This implies that multiple delivery systems of substantial size must be used, providing opportunities for defenses to blunt a chemical attack, thus further raising the weight of attack needed to achieve nuclear-comparable results.

Additionally, a program of passive protection measures can substantially reduce the residual threat of chemical weapons. Given such a program, and assuming timely warning, civilians could remain in at least makeshift shelters, and, depending on the quality of the shelter, wear protective masks if needed. Causing large numbers of casualties among civilians *thus protected* would require far heavier quantities of agents in order to ensure that sufficient amounts of chemical agents to produce fatalities would penetrate through the protection of buildings and masks.

Military forces required to keep fighting also can be protected with masks, suits, CW detectors, antidotes, and decontamination. However, depending upon ambient temperature, training levels, required activities, and other factors, such protection can substantially reduce the efficiency of military personnel, thus requiring more time, personnel, or equipment to accomplish many military tasks. On balance, while the associated political, financial, and manpower costs would be substantial, the allies could configure their forces so that the casualties that could result from CW attacks by any foreseeable regional enemy would be minimal, and the forces could achieve their military

goals despite the burdens of chemical protection. Thus, the residual threat posed by CW is far smaller than that of nuclear weapons.

Biological weapons pose a particularly troubling threat. First, the weight of BW agent required for a devastating attack against an unprotected population is orders of magnitude less than that required for CW agents. Thus, BW attacks sufficient to destroy the populations of cities can be delivered by means that are extremely difficult to interdict. For example, a small drone could spray out as little as 6.5 kilograms (kg) of aerosolized anthrax in a crosswind line tens of kilometers upwind of a city. The resulting lethal cloud could drift over the city causing hundreds of thousands of deaths within as little as 48 to 72 hours. Such an attack would most likely be done at night so as to avoid the ultraviolet light of the sun, which kills most biological agents in a matter of hours.[1]

BW also is particularly troubling because, in a matter of a few weeks, easily acquired and innocent appearing facilities, equipment, and materials can allow the manufacture of sufficient quantities of biological agents to inflict massive casualties on unprotected populations. Thus, in the absence of comprehensive and intrusive monitoring arrangements, we have little chance of knowing whether a state is manufacturing a potentially devastating BW capability, of preventing its manufacture, or of destroying it by military means.

Taken together, these characteristics of biological weapons mean that it is extremely difficult to prevent a reasonably competent and determined opponent from delivering biological weapons against concentrations of personnel. Thus, *defense against a biological attack must emphasize protection of personnel jeopardized by agents arriving in their vicinities.* If this cannot be done well, biological weapons will pose a *residual threat* that is orders of magnitude greater than that posed by chemical or nuclear weapons. Worse yet, biological weapons using agents that are highly contagious, and for which US, UK, and their allies have no ready counters, may pose a global threat greater than posed by a large-scale nuclear war. The fundamental question is thus: how well can targets be protected from BW agents delivered into their immediate vicinities?

III. PROTECTING AGAINST BW ATTACKS AT THE TARGET

A. Vaccines

In concept, the most attractive defense against BW attack would be to develop inexpensive and effective oral vaccines to protect target populations. In fact, vaccines against some potential BW agents exist, and some of these vaccines have been

stockpiled. Further, extensive research is being done to develop new vaccines against additional potential BW agents. Vaccines cannot be the complete answer, however, for a variety of reasons.

First, vaccines do not exist for a number of diseases that are considered usable for biological warfare. In addition, new strains of naturally occurring diseases can appear from time to time, either as natural mutations of the older variants of the disease, or as the result of efforts to create new BW agents. Available vaccines may be ineffective against these new strains.

Second, even where vaccines do exist against a disease, they may not be effective when victims are exposed to the disease in the unnatural ways that typify biological warfare. For example, some plague vaccines are generally ineffective when the disease is introduced into the body via inhalation of an aerosol rather than via flea bites. In addition, vaccines that are capable of countering agents introduced into the body in quantities typical of natural disease transmission can be overwhelmed by the far larger concentrations that may be delivered in BW attacks. Vaccines also have other limitations that can reduce their potential utility. They usually have to be administered well in advance of potential exposure, can require multiple boosters over a period of weeks to become fully effective, can cause adverse reactions in some recipients, can fail to be effective for others, and can be costly.

Third, it can be difficult to anticipate what diseases to vaccinate for. Vaccinating for several diseases to hedge against such uncertainties is more expensive, although polyvalent vaccines are being developed. In addition, the effects of multiple simultaneous vaccinations could cause problems, especially for the very young or the old.

Despite these limitations, vaccines can play an important role in defending against BW at the target. They can save potential victims who have not received overwhelming doses of the agent they protect against. They can undercut the effectiveness of an opponent's BW attack capabilities, perhaps dissuading BW use in wartime, or increasing the difficulty of creating an effective BW threat in peacetime. Vaccines can also help to maintain the confidence of those who might be at the greatest risk of being attacked.

In summary, though vaccines can play an important complementary role in defending against BW, they cannot be the complete answer. Thus, while development of improved vaccines should be pursued, other protective measures are clearly needed.

B. POST-EXPOSURE MEDICATION

Antibiotics, antidotes, and antitoxins are another important way to limit the effects of a BW attack, but they too leave significant gaps. Effective post-exposure medications have not yet been found for some known BW agents. In addition, some diseases for which otherwise suitable post-exposure medications exist cannot be treated effectively once they have progressed far enough to present physical symptoms.

Even when effective medications exist, and when the appearance of symptoms does not imply an already irreversible situation, proper and timely diagnosis may not be possible. Because some diseases have similar symptoms at onset, diagnosis can easily be confused until the disease worsens or blood tests can be completed. Simultaneous use of more than one agent can also confuse diagnosis. Confused diagnoses, or the use of multiple agents, can cause major problems when the drugs needed to treat one possible disease are incompatible with those needed to treat another.

As with vaccines, massive doses of BW agents can overwhelm treatment by otherwise effective medications. In addition, poorly controlled use of antibiotics can lead to the appearance of resistant disease strains. Finally, the vast numbers of people that could be simultaneously exposed to a BW attack, whether actually affected or not, could exceed the maximum practical capabilities of emergency medical treatment facilities, diagnostic laboratories, testing materials, and stocks of drugs. Clearly, something more is needed to prevent these capabilities from becoming swamped.

C. Simple Protective Masks

A particularly promising additional protective measure is a face mask, *since the only practical way to cause mass casualties with BW is to use agents that attack through the respiratory system*. Introducing BW agents via the digestive system is not practical, provided foods are reasonably carefully prepared, and the water supply is protected by a modern purification system or is sterilized by boiling or with chemicals. A few toxins are known to attack through the skin; an example is "T-2," one of the many varieties of tricothecene mycotoxins. Such materials are not attractive as weapons of mass destruction however, as large amounts are required to produce lethal effects. In addition, simply washing the skin provides effective decontamination. Thus, the principal risks arising from BW attack are from agents that attack through the respiratory system.[2]

Masks that can protect against BW attacks through the human respiratory system can be far simpler, cheaper, and less burdensome than those required to protect against

chemical agents. This is because filters that can remove biological warfare agent particles from the air are far easier to design and manufacture than the kinds of filters needed to remove CW agents. [3]

As the CW protection that is provided to many armed forces protects against BW attacks as well, a simple BW mask has two primary values: 1) its potential to protect civilians from BW attacks, and, 2) its potential for use by troops to avoid the larger burdens of wearing the CW mask, when chemical attack can be safely ruled out. Note that a given weight of BW attack can cover far larger areas with lethal concentrations of agent, thus requiring much greater numbers of personnel to wear their CW masks and accept the associated burdens. The next several sections concentrate on the use of simple BW masks by civilians; their potential value to military personnel is discussed later.

Clearly, if a cheap and sufficiently effective BW mask can be provided to civilians, it should be possible to reduce the residual threat posed by BW attacks well below that posed by nuclear weapons. The question is whether it is practical to equip large numbers of civilians with such masks, and whether such protection can be expected to have the desired effects.

IV. AVAILABILITY OF SIMPLE BW PROTECTIVE MASKS

Masks that can provide the necessary high levels of protection against BW attack are already available commercially. These masks are commonly used to protect workers in dusty environments containing radioactive or otherwise harmful particles. They are also sold in hardware stores for household use, and are effective in protecting hospital staff from diseases spread by sneezes.

In fact, during preparations for Operation Desert Storm, the Chemical and Biological Defense Establishment of the United Kingdom tested a simple dust mask available on the European market. This mask, which cost the government less than $4, allowed leakage of only 0.2% of the 1- to 5-micron-sized particles that would present a hazard in the event of BW attack. A higher quality, but approximately equal cost mask made for the US market limited penetration to only 0.01% of the 0.8-micron-sized particles in the outside atmosphere, implying even greater efficiency for larger particles in the 1- to 5-micron range.[4,5] In fact, a number of manufacturers and a variety of different masks are available to choose from.

The achievement of such limited penetration requires careful fitting of the mask, particularly around the nose. In the assessments provided below, we assume that any

civilians to be protected would be provided at least with clear written instructions on how to adjust and test the fits of their masks. We also assume a leakage rate of 0.1%, which is slightly better than the rate for the poorer of the two masks mentioned above. Further comments on how to achieve good mask fits are provided in section VII, below.

V. GAUGING THE RESIDUAL THREAT POSED BY BW WHEN MASKS ARE AVAILABLE

To gauge the residual threat posed by biological weapons, one must first ask what it is about nuclear, biological, and chemical weapons that makes them weapons of mass destruction. As outlined in the arguments presented in section II above, we believe that a very good measure of the ability of these weapons to cause mass destruction is the *reciprocal of the weight or volume of material that must be delivered in the vicinity of the target* to cause devastating effects. The value of this measure can be illustrated by considering two extreme examples. If a pinch of some kind of dust thrown into the air inside a city would kill most of its inhabitants, the destruction of a city could be simply a matter of choice for an attacker. But, if destruction of the city were to require the equivalent of a supertanker of some kind of fluid to be sprayed over it, defense of the city should be a tractable problem. Note that, in the former case, the reciprocal of the weight, our measure of mass destruction potential, is many orders of magnitude greater than in the latter.

To assess the effects of masks and other protective measures on the *residual threat* posed by BW, we must estimate how much more agent would have to be put into the environment in order to ensure that sufficient amounts would penetrate through the protection of buildings, masks, and any other protective "filters" to be deadly.

As a specific example, section II stated that an unprotected city could be poisoned effectively with as little as 6.5 kg of aerosolized anthrax. If its population were equipped with masks of the kind mentioned in section IV (0.1% leakage or less) and could use them effectively (a matter to be discussed further below), the density of agent in the surrounding atmosphere would have to be raised by a factor of at least 1,000 to make the atmosphere reaching the nose and mouth as deadly as without masks.. To a first approximation, this would require attacking the city with at least 1,000 times as much agent, or, in this case, at least 6500 kg of anthrax.

Similarly, if the population of the target city were to shelter themselves in interior rooms whose doors were sealed with sticky tape, the amount of agent penetrating to potential victims would be reduced by at least another factor of 10.[6] In this case, the

total weight of anthrax that would have to be launched at the target city to effectively destroy its population would become at least 65,000 kg.

Covert delivery of attacks of this weight is impractical. Instead, substantial and readily detectable delivery vehicles would be required. The numbers of such delivery vehicles could be raised yet further by defenses deployed by the allies. If, for example, missiles had to be employed to deliver the 65,000-kg anthrax attack postulated above, and an ATBM system that could limit the number of missiles reaching the target city to 10% were present, then at least 650,000 kg of anthrax payload would have to be launched by the attacker. Launching this amount of payload at a target city would require the equivalent of more than 3250 SCUD missiles, an absurd proposition. [7]

Finally, an opponent's preparations for attacks of even a small fraction of this magnitude would surely provide warning signs far easier to detect than those associated with BW attacks of the minute size needed when a target has not been protected. Such warning signs should enable more effective and timely political and military actions to blunt the impending BW attacks.

Implementing any of these defenses would take considerable preparatory effort. It would also require the deployment of detection systems and the adoption of well understood means of warning target populations that BW attacks were imminent. Neither civilian populations nor military personnel can be expected to remain in shelters or to wear protective masks all the time.

In sum, protecting against BW at the target with simple masks and shelters can set up opportunities for other protective measures to become more effective. Warning, masks, and shelters force the BW attacker to deliver agent in amounts where detection would be likely and active defenses and prelaunch attacks could be effective. Additionally, even where masks and shelters do not totally prevent exposure to BW agents, they can reduce exposure below the levels at which vaccines would be overwhelmed, to levels more typical of natural exposure to disease, and for which currently available vaccines have been designed.

Finally, while practical considerations are likely to limit achievable total protection factors to values below the total of 100,000 suggested in the above example, substantially smaller protection factors can go a long way to reduce the residual threat posed by BW. The point is that the danger from BW attack can be massively undermined by relatively practical measures. In fact, the comparisons presented below indicate that the threat posed by BW is more responsive to simple protective measures than the threat

posed by chemical weapons, and vastly more responsive to protection measures than the threat posed by nuclear weapons.

VI. COMPARING THE RESIDUAL THREATS POSED BY NBC WEAPONS

We can estimate the relative magnitudes of the *raw* threats presented by nuclear, biological, and chemical weapons by calculating the reciprocal of the payload weights that would have to be launched against an *unprotected* city to cause as many deaths as would a single one-megaton-yield nuclear weapon. Our calculations of such estimates are explained in notes 1,8, and 9 at the end of this paper. These raw threat estimates for each class of weapon are shown by the three bars on the left in Figure 1, below. The *residual* threats posed to a city protected by active defenses in all three cases, and by masks and shelters against CW and BW, are shown on the right.

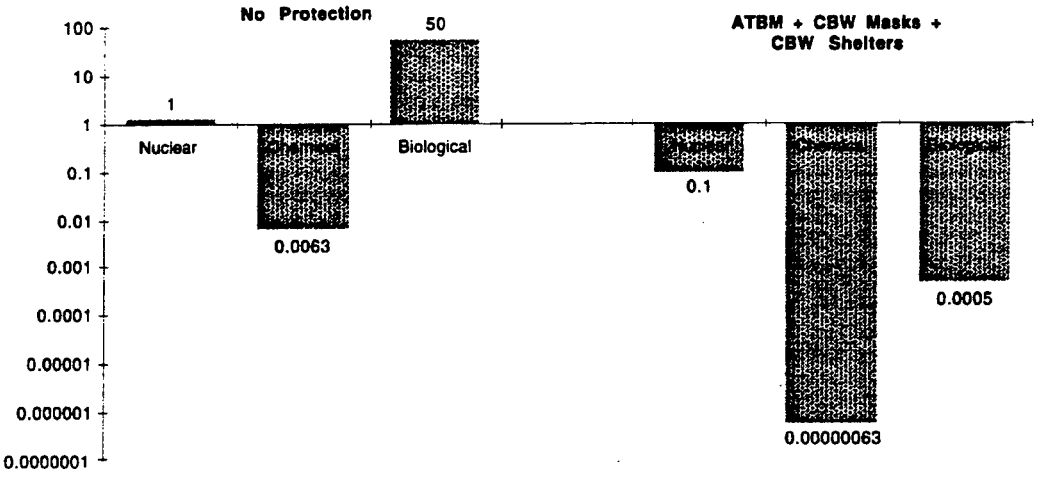

Figure. 1 Estimated Relative Magnitude of Threats Posed to Civilians by Nuclear, Chemical, and Biological Weapons

It should be noted that these are point estimates only, and are clearly subject to many uncertainties. Nevertheless, the *differences* in relative sizes of the raw and residual threats posed by the three types of weapons are of the right order of magnitude. It can be seen clearly that the combination of active defenses, simple protective masks, and shelters reduces the BW threat by 5 orders of magnitude, at least 3 of which come from the mask, 1 from sheltering within buildings, and 1 from the assumed missile defense. Thus, the threat of BW attack drops from approximately 50 times that posed by a nuclear weapon against an *unprotected* city to 5 ten-thousandths of the threat posed by a nuclear weapon against a *protected* city.

Alternatively, one can compare the residual to the raw threats posed by BW and nuclear weapons, respectively. In this example, the BW threat is at least 4 orders of magnitude more responsive to the defenses that can be deployed against it than the nuclear threat is to the single type of protection that can be deployed against it, active defenses. In other words, *efforts to protect populations from BW attack will be rewarded far more readily than those made to protect them from nuclear attack.*

VII. SOME PRACTICAL QUESTIONS

Some practical questions must be answered to assess the potential strategic benefits of a simple BW mask. First, *are such masks affordable* for states or regions that could be subject to BW attack? While the defense expenditures of some states and populations are very small, the general answer to this question has to be yes. For example, the entire urban populations of Saudi Arabia, Syria, and Israel (approximately 24 million) could have been equipped with such masks during Operation Desert Shield for $90 to 100 million. This is roughly the price of three of the several thousand tactical aircraft involved in Operation Desert Storm.

If the citizens are to be spared the necessity of wearing their masks as continuously as possible during periods when the potential for BW attacks is high, sensors to provide warning of actual attacks would also have to be purchased. Several millions of dollars more might be required for each concentration of population to be provided with warning of a large-scale attack.

Producing and procuring large numbers of masks for stockpile could reduce their costs. Even guaranteeing that masks would be quickly available for sale would be useful. A manufacturer should be willing to maintain an extra inventory of in-production commercial masks for not much more than the cost of the capital thus tied up. At the current prime rate, the interest cost on the $90 to 100 million in capital tied up in the example inventory of 24 million masks mentioned above would come to less than $10 million per year.

A second practical question is, *would target populations be willing to wear such masks?* Populations at risk to BW attack would have to be given warning of the possibility of such attacks, and encouraged to wear masks as much as possible during periods of danger. The kinds of masks required to provide good protection against BW agents are not significantly burdensome to wear, and the potential dangers of not wearing a mask could be made known.

While the absence of large-scale chemical attacks in the World War II eventually led to a relaxed attitude toward CW protection, urban populations in Britain and a few other countries were issued chemical protective masks; many carried them around during the early years of the war. Both Sweden and Switzerland have policies of providing total defense for their populations, which includes programs aimed at providing practical protective measures against nuclear, biological, and chemical weapons. In particular, Swiss homes have shelters provided with filtration systems, and the head of household is provided with a personal respirator, in his capacity as a member of the Swiss Armed Forces.

Israel also has a well-developed program for protecting its citizens with masks. A variety of models are available to allow protection for all citizens including infants, small children, the aged and infirm, and special cases such as those who insist on retaining beards that prevent effective use of the simplest types of masks. Excellent manuals describing proper mask use are available to Israeli citizens.[10] New masks employing lightweight air pumps to provide breathing air under positive pressure are also being developed. These will essentially eliminate the risk of poor fits that allow agents to leak into the masks. They will also eliminate the psychological burden felt when wearing current types of masks that require noticeable effort to draw in air. This Israeli program reflects widespread willingness of the citizens to make use of CW civil defense measures. Substantial numbers of urban Israelis wore relatively burdensome CW masks as a precaution against the possibility that Iraqi missiles fired at them during Operation Desert Storm were armed with CW warheads.

Today, citizens in some countries already make a habit of wearing "courtesy masks" in crowds, masks that are generally similar to those referred to in section IV, above. The wearing of such masks is becoming more common and acceptable in areas that have high concentrations of smog, such as Japan and southern California. Further, masks of the type needed are commonly sold in hardware stores for use when working in dusty or chemically contaminated environments. Finally, Indian citizens frightened by the apparent breakout in 1994 of pneumonic plague in their country wore scarves over their faces, and Indian street vendors did substantial business selling a variety of commercial dust and surgical masks.[11]

Even if entire target populations could not be counted on to wear masks during a BW attack, their ready access to masks could help discourage a BW attack. Small initial attacks should have less than strategic effects, and would drive the surviving target populations to wear their masks, thus undercutting the effectiveness of later attacks. This

could eliminate an aggressor's option to make graduated, but politically effective use of BW to force the allies to give up their intervention plans and disengage. If an aggressor launched large-scale surprise BW attacks to cause massive casualties, the allies might be lead to raise their war aims beyond the stakes that the aggressor intended to risk in order to win the issue at hand.

Achieving and maintaining a good fit is a requirement for obtaining the mask effectiveness projected above. One of the masks mentioned in section IV comes in two sizes and has been determined to fit 95 percent of the population well enough to prevent them from smelling samples of a test aerosol. Additional sizes and instruction on how to achieve a good fit would be necessary. Beards will prevent a good fit, requiring that they be shaved off, or that a more complex protective hood be worn. (Such hoods are also already available commercially.) Because large-scale BW attacks are most likely to take place at night, the mask must remain well fitted while sleeping. This might require better positioning straps or other means for helping the mask to remain in place.

There are other practical problems to be solved. For example, masks are not a practical solution for infants, who require other protective measures such as confinement to a room provided with filtered air, or the use of crib covers fitted with filter material. In addition, means must be found for expeditiously distributing masks and other protective equipment when the potential for BW attacks arises. In addition, recipients must be instructed on their use. Further, political constraints may prevent distribution of masks and instruction in their use much in advance of need. [12,13]

VIII. POTENTIAL MILITARY AND OTHER VALUES OF A SIMPLE BW PROTECTIVE MASK

A simple BW mask also could be useful to military forces. Because BW agents are so much more toxic than CW agents, far larger areas can be made hazardous with a given amount of agent. Further, greater toxicity allows a wider variety of ways to expose forces to BW attack. This implies that an opponent would find it far easier to impose some burden of protection and risk on large numbers of forces with BW agents than with CW agents, thus increasing the value of equipping them with less burdensome BW masks. The British Army followed an analogous policy of providing simpler, less burdensome partial protection against CW for its troops. This took the form of a facelet that provided useful protection against CW agents. It was worn continuously, whenever there was a potential risk of CW being used, and provided protection until respirators could be donned for full protection.

Thus, even forces equipped with CW protection may find it useful to carry BW masks, which are relatively light and substantially less burdensome to use than the standard CW mask. Certainly sleeping in a simple BW mask would be far more restful than sleeping in the standard CW mask. The standard US CW mask, for example, can be very hot because it covers most of the head with air-impermeable material.

A specialized BW mask also could reduce the penalties to allied forces of not yet having a BW detector with the broad capabilities currently sought. Low-burden BW masks could be donned whenever suspicious levels of dangerously sized particles were detected in the atmosphere. The delays currently needed to determine the exact nature of such particles would then be more tolerable.

Stocks of rapidly transportable simple BW masks also could be maintained as a means of coping with a BW terrorist campaign. Masks may be particularly effective in this case, because the volumes and concentrations of BW agents employed may not be as high as those that a better equipped regular military opponent could deliver. Certainly, in the aftermath of the first attack, populations would be anxious to protect themselves.

Even more generally, BW masks can be a powerful tool for limiting the spread of contagious diseases, whether the product of human mischief or not. They can block what is far and away the most dangerous means of transmission—the breathing of air contaminated by the sneezes and coughs of the infected.

Finally, to the extent that a simple mask can prevent BW from emerging as a threat comparable to or even greater than that posed by nuclear weapons, it could render moot the question of whether the US needs to consider nuclear retaliation as a deterrent to large-scale use of BW.

IX. ADDITIONAL CAUTIONS

While a simple BW mask may play a very important role in reducing the threat of biological warfare, it is not a complete and final answer for a variety of reasons. For example, advances in biotechnology may open the possibility for practical BW agents that can attack through the skin, or present other challenges.

Further, even with a very well implemented program to protect populations and forces from BW attack, a large-scale BW attack can cause great suffering to a state that experienced it. For example, a city of a million inhabitants that had adopted a BW defense strong enough to save 95% of its population would sustain 50,000 casualties. Still, while a potential calamity of this magnitude would be a serious consideration in any

leader's assessments, it is not nearly as disastrous as the potential death of most or all of a state's urban citizens.

Finally, the foregoing analysis shows that masks provide the most effective defense against BW by working synergistically with other protective measures, including warning systems, shelters, vaccines, and active defenses. Thus, a mask program should supplement, not replace, other measures to blunt the potential of BW attacks.

X. FINAL OBSERVATIONS AND CONCLUSIONS

This short discussion indicates that a simple BW mask appears to have considerable promise as a tool for keeping the threat of biological warfare from rivaling or exceeding that posed by nuclear weapons. Consequently, an aggressive program to exploit its potential seems appropriate.

Where the primary responsibility should lie for pursuing this kind of BW "civil defense" capability is an important issue. Responsibility for civil defense of the US has been managed by the Federal Emergency Management Agency. The US Department of Health and Human Services and some of its subordinate agencies, such as the Centers for Disease Control, should have an interest in the potential of a mask program to supplement other measures for controlling the outbreaks of epidemics. Certainly, the US Defense Department should be responsible for any program to supplement current CW defense for its personnel with a specialized BW mask, as well as for contingency programs to help protect future coalition partners from BW attack. In sum, a program to improve BW defense with a simple mask would cut across the responsibilities of many parts of the US government.

Still, unless specific responsibilities for exploring the potential contribution of a simple BW mask are assigned to some specific agency, it is unlikely to get serious attention. Given the broader BW expertise of the Department of Defense, and the near-term potential for BW to have strategic effects on US decisions to intervene with military forces overseas, there appears to be a good case for assigning to the DoD the lead responsibility for a program to aggressively develop and exploit the potential of a simple BW mask.

Finally, it may be useful to look from a longer historical perspective at the question of controlling disease epidemics.[14] Epidemics have cut wide swaths through humanity for thousands of years. They have come about as a result of contacts between animal and human populations that could tolerate such diseases and those that could not.

Indeed, diseases that pose lethal threats to humans reside all around us. Advances in medicine, sanitation, common practices for personal hygiene, communications, and institutional preparations for rapid control of disease all are responsible for the absence of epidemics threatening substantial fractions of mankind in the last 50 years. Almost surely, this collection of tools has the capacity to blunt the effect of any purposeful effort to subject large populations to deadly disease.

The main difference between the disease control task posed by natural disease and that posed by biological warfare is that the former tends to first appear with discovery of a small number of cases in a few locations, while the latter could involve near-simultaneous infection of many thousands or more people in numerous geographically separated attacks. Such an enormous challenge will only be answered by means that have been planned in advance and that can be implemented by ordinary citizens, rather than trained specialists. Viewed in this light, simple masks and warning systems that provide effective protection against any BW agent that attacks through the respiratory system are clearly very powerful tools for disease control (and BW counterproliferation), particularly in connection with other protective measures.

Contingent adoption of such a hygiene measure will be similar to relatively simple changes in behavior that humans have developed for many hundreds of years to prevent disease and its spread. By the 12th century, the Chinese had learned the value of swabbing the noses of their children with cotton rubbed in the infections of smallpox victims. By the sixteenth century, Christian ports on the Mediterranean had all learned to quarantine arriving ships for 40 days. Nomadic tribesmen of the Eurasian steppe region have long considered it bad luck to camp close to marmot colonies showing signs of sickness. Modern populations should be pleased to learn that a relatively straightforward behavioral change, based on a very simple piece of modern technology, can offer a good first step toward countering the threat of BW.

NOTES

1. A mathematical model widely employed by the US Department of Defense was used to estimate the casualty-producing effects of chemical and biological weapons. Assuming optimal weather conditions, a night attack, and agent and dissemination technology equal to the best achieved by the US, the model estimates that 0.65 kilograms of anthrax, dispersed as an aerosol along an upwind line, could cause 50% casualties over an area of 232 square kilometers. This coverage area was selected to facilitate the comparisons of the threats posed by NBC weapons that are presented later in the paper.

   An opponent could not confidently expect to bring such well-tuned agent and dissemination technologies and attack conditions together, however, and the likely conservatism of military planners suggests that somewhat heavier concentrations would be used to hedge against the possibility of less-than-expected effectiveness. Thus, we will assume that a practical estimate of the agent weight required for this attack would be 6.5 kilograms. This is still considerably less than agent requirements estimated by Steve Fetter in similar calculations. [see "Ballistic Missiles and Weapons of Mass Destruction: What is the Threat? What Should be Done?" International Security, Volume 16, No. 1, ISSN 0162-2889, Summer 1991]. It is also considerably less than the estimates one can create by scaling CW agent requirements for an equivalently lethal city attack by the ratio of anthrax to CW weights needed to create equivalently lethal volumes of air. (1/1000 for anthrax wt./sarin wt.)

2. During the time that the US maintained a program to develop BW weapons, it only required lab and production personnel to wear a simple rubber mask with a cloth filter that left the eyes and ears completely exposed. In addition, in thousands of US tests with aerosols, none produced conjunctivitis in either lab animals or humans. This past practice and experience supports our argument that attacks through the respiratory system are the significant problem.

3. In order to be effective, BW aerosol particles must be in the 1- to 5-micron size—small enough to be breathed in, but not so small as to be easily breathed out. Such particles can be removed by what are essentially fine dust filters. CW agents are normally gaseous materials that must be removed from breathing air by using activated charcoal to absorb the high boiling point vapors; they do not normally take the form of particles.

4. Prices and general technical data provided by the 3M Corporation, esp. Jeffrey Preston and Craig Colton. See "1992 POPS Catalog Reference Guide," 3M Part Number/National Stock Number, Federal Government Respiratory Protection Catalog for Department of Defense and Civilian Agencies, Worldwide Services. Information on UVEX masks was provided by Michael Fuchs.

5. Mask efficiency estimate drawn from Shu-Kang Chen, Donald Vesley, Lisa Brosseau, James Vincent, "Evaluation of Single-Use Masks and Respirators for Protection of Health Care Workers Against Microbacterial Aerosols," *American Journal of Infection Control,* Volume 22, No. 2, April 1994.

6. Estimate based on information provided by Col. William C. Patrick III, US Army (ret.), President of BioThreats Assessment, formerly director of the US Army's BW program.

7. Effective dissemination of BW agents delivered by ballistic missile requires the use of dispersible submunitions or devices for blowing aerosolized or finely ground dry agent overboard in the final moments before the missile impacts the ground. Either way, a modest fraction of the total payload weight of the missile becomes effectively disseminated agent. The BW dissemination system described in note 8, below, delivers 6.5 kg of agent with a total weight of approximately 20 kg (37% of total weight is delivered agent). Suitably quick dissemination of larger amounts of agent would require a dissemination system somewhat less heavy than suggested by scaling the total weight up in proportion to the weight of agent to be delivered. Steve Fetter (op cit) assumes that 30 kg of BW agent could be effectively delivered by a missile with a total payload weight of about 1000 kg (3% of total weight is delivered agent). For purposes of our threat comparisons, we assume a SCUD-like missile with an 800 kg payload could deliver approximately 200 kg of BW agent.

8. A commonly used "rule of thumb" for estimating potential casualties from the detonation of a nuclear weapon over a modern city is to assume that all the population within the range at which the overpressure generated by the weapon would be 6 pounds per square inch or greater would be killed, and all beyond would survive. Of course, some within this range would survive, and some beyond would die, but these two effects are assumed to be roughly equal. This rule of thumb implies that a nuclear weapon with a yield of one megaton would cause the equivalent of total destruction over an area of approximately 116 square kilometers. This estimate is probably conservative for a variety of reasons. Perhaps the most important is that it only considers the immediate effects of the weapon.

   For purposes of our calculations, we assume that a 1 megaton yield nuclear weapon would weigh 1000 kilograms. Achieving a one megaton yield in a 1000-kilogram package requires considerable technical sophistication. The US crossed this threshold in the late 1950s, and China is reported to have crossed it within the last several years. Nuclear proliferators would probably start well below this yield-to-weight ratio, as reaching it requires a design employing thermonuclear fusion, rather than all fission. Alternatively, exploitation of modern computers and weapons simulation codes, or the "reverse engineering" of a purloined Russian thermonuclear weapon, might allow quick progress to high yield thermonuclear weapons that are light enough to deliver to targets with missiles or aircraft. See Thomas B. Cochran, William M. Arkin, and Milton M. Hoenig, book by Natural Resources Defense Council, Inc., *US Nuclear Weapons Data Handbook*, volume 1, *US Nuclear Forces and Capabilities,* Ballinger Publishing Company, Cambridge Massachusetts, 1984.

Our comparisons of the relative threats posed by nuclear and biological weapons are constructed as follows. Note 1 states that 6.5 kilograms of aerosolized anthrax can cause 50% destruction of the population of an area of 232 square kilometers. This is equivalent to the 100% destruction of an area of 116 square kilometers estimated for the 1000 kilogram nuclear weapon. Dissemination of dry anthrax could be done by a system of the kind designed by the US when it had an offensive BW program. This system ground up dry cakes of agent and blew the resulting fine powder into the slipstream of a delivery aircraft. A system large enough to deliver 6.5 kilograms of dry anthrax can be built with a total weight of approximately 20 kilograms. [Estimate based on information provided by William Patrick III, cited in note 6]

Following the arguments presented in section V, we take the relative weights of weapons of mass destruction sized to do equivalent damage as an appropriate measure of the relative magnitudes of the threats they each present. Taking the magnitude of the threat posed to an unprotected city by our example nuclear weapon as 1, the relative magnitude of the threat of a BW attack against an unprotected city would thus be 1000 kilograms (the weight of the assumed nuclear weapon) divided by 20 kilograms (the weight of an equivalently destructive BW weapon) = 50.

To estimate the residual threat posed by nuclear weapons when an active defense system is present, we assume that such a defense system might be good enough to prevent significant damage by 90% of the nuclear delivery vehicles it sees. Faced with such a system, a nuclear attacker thus would have to launch an average of 10 nuclear delivery systems toward a target in order to destroy it. In this case, the residual threat posed by nuclear weapons would be 1/10th that posed by nuclear weapons against an unprotected target. If the threat posed by nuclear weapons against an unprotected city is taken as 1, the residual threat posed by such weapons would thus be 1/10th. Note that it is not unreasonable to assume that a nuclear proliferator could aspire to at least this large a weapons inventory.

9. The same mathematical model referred to in note 1 above estimates that a 1000-kg warhead delivering submunitions filled with the nerve agent Sarin could lead to 50% casualties for an unprotected population over an area of 1.47 square kilometers, assuming optimal weather conditions. Thus, matching the effects assumed for a 1 megaton nuclear weapon which, as calculated in note 8, would cause the equivalent of 100% of an area of 116 square kilometers, would require enough CW agent to destroy 50% of 232 square kilometers. This would come to 232/1.47 x 1000 kilograms = 158,000 kilograms. The relative magnitude of the threat posed by CW attack is thus 1000 kilograms (the weight of the example nuclear warhead)/158,000 kilograms = 0.0063.

   Based on tests done by the Israeli Defense Force, we assume effective attack of populations that have well-fitted chemical protective masks, and are well sheltered in buildings, would require at least 1000 times more chemical agent. If we also assume an ATBM with a 10% leakage rate, then achieving destruction equivalent to that done to an unprotected city by the example nuclear weapon requires that 1,580,000,000 kilograms of CW payload would have to be launched against the target city. This

means that the residual threat posed by chemical weapons against a city thus protected would be 1000/1,580,000 = 0.00000063.

Similarly, based on the assumed effectiveness of the various BW defenses stated in section VI, the residual threat posed by BW would be 1/100,000th of that posed by BW against a completely unprotected city, or 0.00050.

The assumed protection factor of 1000, 100 for a CW mask and 10 for a sealed shelter, is taken from: "State Comptroller Faults Gas Mask Distribution", *The Jerusalem Post* in English, 15 April 1991, p.7, cited in FBIS-NES-91-075, 18 April 1991, p. 25.

Using a lower yield-to-weight for nuclear weapons in these calculations would make CB attacks against unprotected populations appear more threatening relative to attacks with nuclear weapons. Note also that the damaging overpressures created by nuclear weapons scale down more slowly than proportional to yield. Thus, a nuclear weapon with 1/25th of the yield of a one megaton weapon would cause equivalent damage over an area that is 1/8th the size.

10. Ilan Yeshua, "Chemical Warfare: A Family Defense Manual", *The Jerusalem Post Edition*, published by the Centre for Educational Technology, printed in Israel, 1990.
11. *The Washington Post,* p. A33, October 2, 1994.
12. Training to use masks effectively is required by the US Occupational Safety and Health Administration regulations for hazardous working environments, and OSHA requires masks to be fit tested to ensure their effectiveness. Masks are tested by asking workers if they can detect a standardized sample of perfume sprayed into a covering test hood.
13. A fully effective BW mask program would include peacetime instruction on the use of a mask. It would also test the fit of available sizes of masks on individuals to identify the minority posing special fit problems and requiring tailored masks or hoods.
14. The historical information in this section is drawn from William H. McNeill, *Plagues and Peoples*, Anchor Book, Doubleday, New York, 1977.

Electronic References

Internet Locations

Note: The following URLs are current as of the date of publication

Chemical-Biological Defense Systems Division - *http://www.brooks.af.mil/HSC/YA/yac/yac.htm*

This Home Page consists of unclassified, public access information regarding Chemical-Biological Defense Systems Research and Development projects.

CBIAC - The Chemical Warfare/Chemical and Biological Defense Information Analysis Center - *http://www.cbiac.apgea.army.mil/*

The CBIAC serves to collect, review, analyze, synthesize, appraise and summarize information pertaining to CW/CBD. The CBIAC helps the DoD meet its demanding technological needs and implement its high-priority Research and Development (R&D) initiatives through the prompt and expert application of existing scientific and technical information.

Medical Chemical and Biological Defense - *http://mrmc-www.army.mil/biodef_t.html*

Developing medical defenses for bacterial, viral, or toxin-induced disease is a complex task that requires a concerted team effort from scientists, pathologists, veterinarians, logisticians, and statisticians. In addition to providing medical chemical defense, this program develops medical countermeasures and diagnostic products against biological warfare (BW) threats such as microbial agents and toxins. The goals of this research program are to ensure the sustained effectiveness of U.S. forces in a BW environment and deter the use of these weapons by maintaining a strong medical defensive posture.

Chemical & Biological Sensors - *http://www.spec.com/chem_bio*

State-of-the-art components and systems for solving recently impossible problems.

Chemical and Biological Arms Control Institute - *http://www.capitol.net/~cbaci/*

The Chemical and Biological Arms Control Institute is a nonprofit corporation established to promote the goals of arms control and nonproliferation, with a special, although not exclusive, focus on the elimination of chemical and biological weapons. It fosters this goal by drawing on an extensive international network to provide an innovative program of research, analysis, technical support, and education.

Medical NBC Defense - *http://www.nbc-med.org*

The Nuclear Biological and Chemical Medical (Med-NBC) web page contains extensive medical documentation, training material, audio-video clips, a powerful search engine, and links to other related Internet sites.

Hotlinks to other sites of interest:
Nuclear, Biological, and Chemical Sites - *http://www.nbc-med.org/hotlist/nuc.html*

Hotlinks of interest from the Nuclear Biological and Chemical Medical web page.

Working Group on Biological and Toxin Weapons - *http://www.fas.org/bwc/*

Federation of American Scientists Working Group on Biological and Toxin Weapons Home Page.

Health & Ecological Assessment Home Page - *http://www-ep.es.llnl.gov/www-ep/hea.html*

Lawrence Livermore National Laboratory, Health and Ecological Assessment Division, develops improved methods for measuring and estimating the exposure of biota to radioactive and nonradioactive substances in the environment and the biological effects of those exposures. The Division's work covers the entire spectrum of topics related to the assessment of environmental hazards, from the development of new sensors for the remote detection and monitoring of chemical compounds, through research on exposure estimation, dosimetry, dose-response relationships, and the fate of contaminants in the environment.

Report of the Defense Science Board Task Force on Persian Gulf War Health Effects - *http://www.dtic.mil/gulflink/dsbrpt/*

GULFLINK, Gulf War Illness Homepage *(http://www.dtic.mil/gulflink/)* includes links to research and reports including the following:

- Report of the Defense Science Board Task Force on Persian Gulf War Health Effects
- Report on Possible Effects of Organophosphate "Low Level" Nerve Agent Exposure, August 22,. 1996
- Non-Specific Illnesses in Personnel, August, 1996
- Coalition Chemical Detections and Health of Coalition Troops in Detection Area, August 5, 1996
- A Review of the Mortality of Veterans After Service in the Persian Gulf During Operation Desert Storm and Desert Shield, May 1996
- The Possible Role Of Vaccine Adjuvants in Persian Gulf War Veterans' Illnesses, March 1996

Also includes bibliographies from the National Library of Medicine and the Gulf War Veteran Research Team at the Naval Health Research Center.

Visit DTIC on the Internet at:
http://www.dtic.mil

Additional References

Note: Refer to the order form following the bibliographies for ordering information.

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(U) Crystallographic Studies of the Anthrax Lethal Toxin.

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PERSONAL AUTHORS: Frederick, Christin A.

UNCLASSIFIED REPORT

ABSTRACT: (U) The lethal form of Anthrax results from the inhalation of Anthrax spores. Death is primarily due to the effects of the lethal toxin (Protective Antigen (PA) + Lethal Factor) from the causative agent, Bacillus Anthracis. All the Anthrax vaccines currently in use or under development contain or produce PA, the major antigenic component of Anthrax toxin, and there is a clear need for an improved vaccine for human use. In the previous report we described the first atomic resolution structure of PA, revealing that the molecule is composed largely of beta-sheets organized into four domains. This information can be used in the design of recombinant PA vaccines. In this report we describe additional features of the full-length PA molecule derived from further crystallographic refinement and careful examination of the structure. We compare two crystal forms of PA grown at different pH values and discuss the functional implications. A complete definition of the function of each domain must await the crystal structure of the PA63 heptamer. We have grown crystals of the heptamer under both detergent and detergent-free conditions, and made substantial progress towards the crystal structure. The mechanism of anthrax intoxication in the light of our results is reviewed.

DESCRIPTORS: (U) *LETHALITY, *ANTHRAX, *ANTIGENS *TOXINS AND ANTITOXINS, *CRYSTALLOGRAPHY, *INTOXICATION, *BACILLUS ANTHRACIS, CRYSTAL STRUCTURE, HUMANS, RESOLUTION, CRYSTALS, SPORES, USER NEEDS, DETERGENTS, VALUE, DEATH, REFINING, ATOMIC PROPERTIES, PH FACTOR, VACCINES, BACTERIAL TOXINS, ATOMIC STRUCTURE, INHALATION.

AD-A313 953

BATTELLE MEMORIAL INST
COLUMBUS, OH

(U) A Medical Research and Evaluation Facility (MREF) and Studies Supporting the Medical Chemical Defense Program.

APR 96 117P
PERSONAL AUTHORS: Olson, Carl; Menton, Ronald; Kiser, Robyn; Hayes, Timothy; Mettheese, M. C.

UNCLASSIFIED REPORT

ABSTRACT: (U) Strong and well-defined agent dose 10-hr lethality relations were observed in untreated animals for each agent. The 10-hr agent MLDs for untreated monkeys were estimated to be 80, 43, 8.0, 22, and 7.4 ug/ kg for GA, GB, GD, GF, and VX, respectively. The 10-hr GD MLDs estimated for ATRI2-PAM and ATR/HI-6 treated monkeys were 10 and 13 ug/kg, respectively. Neither oxime provided protection against 2 x GD lOhr MLD. No lethality was observed in oxime-treated animals injected with either GF or VX, even though animals were given doses greater than 15 x agent MLD. Because of this, only four or five monkeys per oxime treatment were used in GF and VX experiments. Treatment with ATR/2-PAM or ATR/H1-6 substantially affected the slope of the agent dose lethality response curves for GA and GB. Larger sample sizes are required to estimate the shallow GA and GB dose lethality curves observed for oxime treated animals. For GA, 79 percent (11/14) of oxime treated animals injected with doses greater than 2 x 10-hr MLD survived at least 10 hr. These data indicate that both oximes provide some protection against a 2 x GA 10-hr MLD. For GB, ATRS2-PAM treated animals were given doses ranging from approximately one to 13 x GB 10-hr MLD, and ATR/H1-6 treated animals were administered GB doses ranging from approximately 0.73 to 2 x 1%hr MLD. In spite of the higher GB doses administered to ATRI2-PAM treated animals survival was greater (718) than for ATR(H1% treated animals (518). All three of the ATR/-PAM treated animals injected with GB doses greater than 2 x 10hr MLD survived. The collected data indicate that ATR/2-PAM provides protection against a 2 x GB.

DESCRIPTORS: (U) *CHEMICAL WARFARE, *LETHALITY, *MEDICAL RESEARCH, *NERVE AGENTS, *LETHAL DOSAGE, *GA AGENT, *GB AGENT, *GD AGENT, *VX AGENT, DEFENSE SYSTEMS, SURVIVAL(GENERAL), DOSAGE, SLOPE, ANIMALS, PREVENTIVE MEDICINE, MONKEYS, OXIMES.

IDENTIFIERS: (U) HI 6, 2 PAM, GF AGENT.

AD-A313 356

ARMY MEDICAL RESEARCH INST OF INFECTIOUS DISEASES, BACTERIOLOGY DIV
FORT DETRICK, MD

(U) Experimental Anthrax Vaccines: Efficacy of Adjuvants Combined with Protective Antigen against an Aerosol Bacillus Anthracis Spore Challenge in Guinea Pigs.

1995 8P
PERSONAL AUTHORS: Ivins, Bruce ; Fellows, Patricia; Pitt, Louise; Estep, Janis; Farchaus, Joseph.

UNCLASSIFIED REPORT

AVAILABILITY: Pub. in Vaccine, v13 n18 p1779-1784, 1995. Available only to DTIC users. No copies furnished by NTIS.

ABSTRACT: (U) The efficacy of several human anthrax vaccine candidates comprised of different adjuvants together with bacillus anthracis protective antigen (PA) was evaluated in guinea pigs challenged by an aerosol of virulent B. The most efficacious vaccines tested were formulated with PA plus Monophosphoryl Lipid A (MPL) in a Squalenel Lecithin/ Tween 80 emulsion (SLT) and PA plus the saponin QS-21. The PA+MPL in SLT vaccine, which was lyophilized and then reconstituted before use, demonstrated strong protective immunogenicity, even after storage for 2 years at 4 deg C. The MPL component was required for maximun efficacy of the vaccine. Eliminating lyophilization of the vaccine did not diminish its protective efficacy. No significant alteration in efficacy was observed when PA was dialyzed against different buffers before preparation of vaccine. PA+MPL in SLT proved superior in efficacy to the licensed United States human anthrax vaccine in the guinea pig model.

DESCRIPTORS: (U) *SPORES, *ANTHRAX, *VACCINES, *BACILLUS ANTHRACIS, BUFFERS, AEROSOLS, PREPARATION, HUMANS, LIPIDS, STORAGE, IMMUNITY, ANTIGENS, ANATOMICAL MODELS, GUINEA PIGS, LYOPHILIZATION, IMMUNOGENS, LECITHIN.

IDENTIFIERS: (U) MPL (MONOPHOSPHORYL LIPID A), SLT(SQUELENEL LECITHIN/TWEEN)

✦AD-A311 911

NAVAL WAR COLL
NEWPORT, RI

(U) American Military Readiness for Chemical and Biological Warfare: A Critical Vulnerability.

JUN 98 25P
PERSONAL AUTHORS: McCarten, Michael D.

UNCLASSIFIED REPORT

ABSTRACT: (U) There has been a proliferation in the production and sale of chemical weapons, biological weapons and the missiles used to deliver them along potential adversaries of the U.S. As this proliferation continues, the likelihood of an attack against the U.S. is increasing. Despite NCA support for a counterproliferation initiative, deficiencies in readiness that existed at the time of the Persian Gulf War persist. Continued deficiencies are due to lack of prioritization at the level of the Joint Chiefs of Staff and the CINCs. These deficiencies constitute a critical vulnerabililty, and as such, place the United States at risk of suffering a strategic defeat.

DESCRIPTORS: (U) *NUCLEAR PROLIFERATION, *MILITARY OPERATIONS, *MASS DESTRUCTION WEAPONS, *BIOLOGICAL WARFARE AGENTS, *CHEMICAL WARFARE AGENTS, UNITED STATES, RISK, PRODUCTION, PERSIAN GULF, COMBAT READINESS, OPERATIONAL READINESS, VULNERABILITY, COUNTERMEASURES.

IDENTIFIERS: (U) *COUNTERPROLIFERATION

✦ Included in *The DTIC Review*, December 1996

AD-A311 793

ARMY MEDICAL RESEARCH INST OF
CHEMICAL DEFENSE
ABERDEEN PROVING GROUND, MD

(U) Gas Chromatographic Separation of the Stereoisomers of Organophosphorus Chemical Warfare Against Using Cyclodextrin Capillary Columns.

MAY 96 6P
PERSONAL AUTHORS: Smith, J.R.; Schlager, John J.

UNCLASSIFIED REPORT

AVAILABILITY: Pub. in Jnl. of High Resolution Chromatography, v19 p151-154, Mar 96. Available only to DTIC users. No copies furnished by NTIS.

ABSTRACT: (U) The synthesis of the organophosphorus nerve agents sarin, tabun, and cyclohexyl methylphosphonofluoridate (GF) produces a mixture of two stereoisomers except for soran where four stereoisomers are produced. Significant differences exist in the reported toxicity and AChE inhibition rates of the various stereoisomers. This makes the ability to distinguish between the different stereoisomers desirable. Five different derivatized cyclodextrin stationary phases developed for gas chromatography were tested for their ability to resolve the nerve agent stereoisomers using a gas chromatograph interfaced to an atomic emission detector. Of the five columns that we examined only the 2, 6-di-0-pentyl-3-0-trifluoroacetyl or 2,6-dl-0-pentyl-3-O-butyryl gamma-cyclodextrins were able to successfully resolve all four soman stereoisomers. The elution order for each column was determined using solutions of isolated soman stereoisomers. Enantiomers of sarin, tabun, and GF were resolved with varying degrees of success on the different cyclodextrin stationary phases. Only the butyryl gamma-cyclodextrin was able to separate the enantiomers of all four of the nerve agents examined in this study. The capacity (k) and selectivity (a) factors were determined for each of the chemical warfare agents successfully separated. The TNO Prins Maurits Laboratory in the Netherlands has previously developed several different chromatographic methods to resolve the stereoisomers of soman, sarin, and tabun. The advantage of the method described here is that commercially available cyclodextrin gas chromatography columns were used to resolve the stereoisomers, thereby facilitating rapid and routine analysis of organophosphorus nerve agents.

DESCRIPTORS: (U) *SEPARATION, *MOLECULAR ISOMERISM, *STEREOCHEMISTRY, *GAS CHROMATOGRAPHY, *CHEMICAL WARFARE AGENTS, *ORGANIC PHOSPHORUS COMPOUNDS REPRINTS DETECTORS, METHYL RADICALS, SYNTHESIS TOXICITY ISOLATION, NUCLEAR RADIATION, PHASE, MIXTURES, ISOMERS, STATIONARY, INHIBITION, CETYLCHOLINESTERASE, NERVE AGENTS, GA AGENT, GB AGENT, GD AGENT.

AD-A309 467

ARMY RESEARCH LAB
FORT BELVOIR, VA

(U) Reduced Volatile Organic Compounds (VOC) Chemical Agent Resistant Coating (CARC) Primer.

MAY 95 16P
PERSONAL AUTHORS: Duncan, Jeffrey L; Escarsega, John

UNCLASSIFIED REPORT

ABSTRACT: (U) The Chemical Agent Resistant Coating (CARC) system is required on all combat, combat support, and essential ground support equipment, plus tactical wheeled vehicles and aircraft, in order to meet the threats of chemical warfare. When the Army required implementation of CARC in FY85, the military specification MIL-P-53022, Primer, Epoxy Coating, Corrosion Resisting, Lead and Chromate Free became the workhorse default primer in the CARC system. Since Federal and local regulations resulting from the Clean Air Act and its amendments restrict the amount of Volatile Organic Compounds (VOC) emitted during the application of protective coatings, the specification was revised in 1988 to include a higher solids material which had a maximum VOC content of 3.5 lb/gal, but there will be lower limits in the future. This report summarizes progress in the investigation of epoxy binder technologies which have the potential for providing equivalent or better performance compared to the present primer, but at a reduced VOC of 2.8-lb/gal maximum.

DESCRIPTORS: (U) *PRIMERS, *COATINGS, *CHEMICAL AGENTS, *ORGANIC COMPOUNDS, *EPOXY COATINGS, UNITED STATES GOVERNMENT, AIRCRAFT, CORROSION, THREATS, COMPOSITE MATERIALS, RESISTANCE, MILITARY VEHICLES, SOLIDS, REDUCTION, LOW LEVEL, PROTECTIVE COATINGS, GROUND VEHICLES, VOLATILITY, BINDERS, REGULATIONS, GROUND SUPPORT EQUIPMENT, CHEMICAL WARFARE AGENTS.

IDENTIFIERS: (U) *CHEMICAL AGENT RESISTANT COATING, CARC (CHEMICAL AGENT RESISTANT COATING), WHEELED VEHICLES, LEAD FREE, CHROMATE FREE, CLEAN AIR ACT, VOC (VOLATILE ORGANIC COMPOUNDS), VOLATILE ORGANIC COMPOUNDS.

AD-A307 327

NAVAL WAR COLL, JOINT MILITARY OPERATIONS DEPT
NEWPORT, RI

(U) The King Has No Clothes: The Role of the Military in Responding to a Terrorist Chemical/Biological Attack.

JUN 96 25P
PERSONAL AUTHORS: Osterman, Joseph L.

UNCLASSIFIED REPORT

ABSTRACT: (U) The use of Sarin by the Aum Shinrikyo cult in the Tokyo subway on 20 March 1995 proved to the world that terrorism had crossed the threshold of weapons of mass destruction (WMD) use. Iraq's revelations of biological/ chemical weapons preparations during the Gulf War has shown the potential for use of these weapons by rogue states. The United States has begun a program of counterproliferation in order to preempt the use of WMD by such elements, however, the ability to respond to the terrorist employment of biological/chemical weapons is glaringly absent. Given the structure, capability and technical expertise in the Federal Emergency Management Agency (FEMA) and the Federal Bureau of Investigation (FBI), the Department of Defense (DoD) will be tasked to conduct the response to such an incident. The geographical Commander in Chief (CINC) and the appointed Joint Task Force (JTF) commander will ultimately be assigned the response mission. Planning, training and coordination is required to develop a force capable of responding in a timely and coordinated manner. The recent initiative by the Marine Corps to develop a Bio/ Chem Response Unit is a beginning, but is very limited in capability. The potential for such a disaster on American soil can no longer be ignored nor can the response to it be considered too hard.

DESCRIPTORS: (U) *WEAPONS, *BIOLOGICAL WARFARE, *CHEMICAL WARFARE, *MASS DESTRUCTION WEAPONS, *TERRORISM WARFARE, DEPARTMENT OF DEFENSE, GULFS, MARINE CORPS, UNITED STATES, DISASTERS, PREPARATION, EMPLOYMENT, TASK FORCES, MASS, DESTRUCTION, SOILS, RESPONSE, MISSIONS, CHEMICAL ORDNANCE, GB AGENT.

IDENTIFIERS: (U) TERRORISM, WMD (WEAPONS OF MASS DESTRUCTION), FBI (FEDERAL BUREAU OF INVESTIGATION).

✦AD-A306 901

GENERAL ACCOUNTING OFFICE, NATIONAL SECURITY AND INTERNATIONAL AFFAIRS
WASHINGTON, DC

(U) Chemical and Biological Defense: Emphasis Remains Insufficient to Resolve Continuing Problems.

MAR 96 44P

UNCLASSIFIED REPORT

SUPPLEMENTARY NOTE: Report to Congressional Committee.

ABSTRACT: (U) For decades, the United States has struggled to prevent the proliferation of nuclear biological, and chemical weapons. Nevertheless, the number of countries that possess nuclear, biological, or chemical capabilities grows each year. As a result, countries possessing these weapons could threaten the interests of the United States in every possible theater of the world. The Gulf War experience exposed (1) weaknesses in the U.S. forces' preparedness to defend against chemical or biological agent attacks and (2) the risks associated with reliance on post-mobilization activities to overcome deficiencies in chemical and biological readiness. Post-conflict studies confirmed that U.S. forces were not fully prepared to defend against Iraqi use of chemical or biological weapons and could have suffered significant casualties had they been used. Units and individuals often arrived in theater without needed equipment, such as protective clothing and adequate chemical and biological agent detectors. Active and reserve component forces required extensive chemical and biological training before and after arrival in Southwest Asia. Medical readiness problems included inadequate equipment and training. Biological agent vaccine stocks, and policies and procedures for their use were also inadequate. While postmobilization and in theater activities increased readiness, equipment and training problems persisted to varying degrees throughout the conflict. Complacency and the absence of command emphasis on chemical and biological defense prior to deployment were among the root causes of this lack of preparedness. We previously reported on these problems in May 1991.

DESCRIPTORS: (U) *BIOLOGICAL WARFARE, *CHEMICAL WARFARE *OPERATIONAL READINESS, BIOLOGICAL WARFARE AGENTS, CHEMICAL WARFARE AGENTS, CHEMICAL AGENT DETECTORS BIOLOGICAL AGENT DETECTORS, WEAPONS, MILITARY RESERVES GLOBAL, THEATER LEVEL OPERATIONS, UNITED STATES, POLICIES DEFENSE SYSTEMS, TRAINING, ATTACK, CASUALTIES, CHEMICAL ORDNANCE, PROTECTIVE CLOTHING, VACCINES.

IDENTIFIERS: (U) PERSIAN GULF WAR.

✦ Included in *The DTIC Review*, December 1996

AD-A306 750

PACIFIC-SIERRA RESEARCH CORP
SANTA MONICA, CA

(U) Taxonomic Model for Performance Degradation in Combat Tasks.

APR 96 134P
PERSONAL AUTHORS: Anno, George H.; Dore, Michael A.; Roth, Thomas J.

UNCLASSIFIED REPORT

SUPPLEMENTARY NOTE: Prepared in cooperation with Micro Analysis and Design, Boulder, CO.

ABSTRACT: (U) A procedure is developed to mathematically synthesize functions for task performance degraded by the effects of environmental stressors including nuclear radiation and chemical warfare agent SARIN (GB) and distilled mustard (HD). The methodology first requires a suitable data base of task performance functions that are integrated with taxonomic scoring weights to characterize various kinds of tasks based on a taxonomy of human abilities or attributes. Second a taxonomy and task scoring system is developed to provide the required taxa data. Five taxons were chosen based on a set of pragmatic criteria applied to represent the five task performance attributes: attention, perception, psychomotor ability, physical ability, and cognitive ability. A task is characterized by subject matter experts (SMEs) who provide scores on a seven point scale for each taxon depending upon the demand individually put on them according to the task. Various statistical tests were applied to assess the preliminary validity of applying the taxonomy developed including correlation among SME raters, and measures of agreement and discrimination regarding taxon scores vis-a-vis symptomatology induced by stressor effects. The mathematical relationships of the task-taxon-task (T3) methodology are developed to illustrate how the task performance data base is generated and utilized to synthesize performance functional parameters for other tasks. Calculations are also performed to illustrate that the T3 methodology is computationally self-consistent and sound. Although developed utilizing data for nuclear radiation and chemical warfare agents, the methodology is general and can be extended to other stressors.

DESCRIPTORS: (U) *NUCLEAR RADIATION, TAXONOMY, *CHEMICAL WARFARE AGENTS, DATA BASES, MATHEMATICAL MODELS, FUNCTIONS, SKILLS, DEGRADATION, PERFORMANCE (HUMAN), SYNTHESIS, TASK FORCES, PARAMETERS, PHYSICAL PROPERTIES, STATISTICAL TESTS, COGNITION, SCALE, WEIGHT, MATHEMATICS, MUSTARD AGENTS, PERCEPTION, GB AGENT, PSYCHOMOTOR TESTS, DISTILLATES.

✦AD-A306 168

EDGEWOOD RESEARCH DEVELOPMENT AND ENGINEERING CENTER
ABERDEEN PROVING GROUND, MD

(U) Protection Factor Testing of the Responder Suit.

JAN 96 72P
PERSONAL AUTHORS: Arca, Victor J.; Ramos, Gabriel A.; Reeves, Dennis W.; Blewer, William K.; Fatkin, David P.

UNCLASSIFIED REPORT

ABSTRACT: (U) Testing was conducted to measure the protective capability of a commercial chemical-protective suit (ResponderTM) against toxic vapors or aerosols. The standard U.S. Army Battle Dress Overgarment (BDO) was also included in the test. Both the ResponderTM and the BDO were worn with an industrial powered respirator and an Army-designed hood. The testing was conducted at the U. S. Army Edgewood Research, Development and Engineering Center on 19-30 Jun 95 and consisted of nine trials, each involving up to four test subjects. In each trial, the test subjects wore the ResponderTM suit for 30 min while performing a series of exercises in a chamber filled with a mustard simulant vapor, methyl salicylate, at a concentration of 50 mg/m3. Vapor concentrations were measured at several locations beneath the suit with passive sampling devices containing the solid adsorbent Tenax. Results show that the ResponderTM suit provides protection equivalent to the BDO when worn with the hood tucked into the collar to direct filtered air into the suit. With wrists taped and with either ankles taped or integral foot covers, the ResponderTM provided protection greater than the BDO.

DESCRIPTORS: (U) *METHYL RADICALS, *TOXICITY, *MUSTARD AGENTS, *PROTECTIVE CLOTHING, *PROTECTIVE MASKS, *CHEMICAL AGENT SIMULANTS, TEST AND EVALUATION, AEROSOLS, AIR, VAPORS, PASSIVE SYSTEMS, SOLIDS, PROTECTION, FILTERS, ARMY, BATTLES, SAMPLERS, FEET, SALICYLATES, ADSORBENTS.

IDENTIFIERS: (U) TENAX, PASSIVE SAMPLING, BDO, CSEPP, PAPR MASK, METHYL SALICYLATE, NBC, JSLLST, CHEMICAL PROTECTION, CDRA, PROTECTION FACTOR.

✦ Included in *The DTIC Review*, December 1996

AD-A306 125

GENERAL ACCOUNTING OFFICE NATIONAL SECURITY AND INTERNATIONAL AFFAIRS WASHINGTON, DC

(U) Chemical and Biological Defense: Emphasis Remains Insufficient to Resolve Continuing Problem.

MAR 96 11P

UNCLASSIFIED REPORT

SUPPLEMENTARY NOTE: Testimony before the House Committee on National Security, Subcommittee on Military Research and Development.

ABSTRACT: (U) We appreciate the opportunity to provide our assessment of the capability of U.S. forces to fight and survive while under attack by chemical and biological agents. Our work was requested by the Subcommittee on Readiness, House Committee on National Security, and addresses early deploying U.S. Army and Marine Corps ground forces. Information was obtained from a wide range of officials to include those in the Office of the Secretary of Defense, the Joint Chiefs of Staff (JCS), the war-fighting Commanders in Chief (CINC), Department of the Army, Headquarters U.S. Marine Corps, U.S. Army Forces Command, U.S. Army Reserve Command, and at corps division, and individual unit levels. We plan to issue a report on our work in April 1996. As GAO and the Department of Defense (DoD) have reported on numerous occasions during the Persian Gulf Conflict (1) many units arrived in the Persian Gulf without needed protective equipment and adequate training, (2) plans to vaccinate personnel to protect them from the effects of biological agents were inadequate, and (3) medical units lacked the ability to treat casualties in a chemically or biologically contaminated environment. U.S. forces would have been highly vulnerable to chemical or biological attack had they not had 6 months after arrival in the Gulf to deal with these shortcomings before offensive operations began.

DESCRIPTORS: (U) *DEFENSE SYSTEMS, *BIOLOGICAL WARFARE, *CHEMICAL WARFARE, MILITARY FORCES (UNITED STATES), MILITARY OPERATIONS, MILITARY RESERVES, DEPARTMENT OF DEFENSE, MARINE CORPS, NATIONAL SECURITY, ENVIRONMENTS BIOLOGICAL AGENTS, PERSIAN GULF, INFANTRY, ATTACK, COMMAND AND CONTROL SYSTEMS, PROTECTIVE EQUIPMENT, CASUALTIES, CONFLICT, CONTAMINATION, MEDICAL SERVICES ARMY, ARMY OPERATIONS, HOUSE OF REPRESENTATIVES.

IDENTIFIERS: (U) GAO (GENERAL ACCOUNTING OFFICE), GENERAL ACCOUNTING OFFICE.

AD-A305 662

ARMY RESEARCH LAB
ABERDEEN PROVING GROUND, MD

(U) Improvements to the U.S. Army Research Laboratory (ARL) Army Unit Resiliency Analysis (AURA) "All Clear" Algorithm.

DESCRIPTIVE NOTE: Final rept. Apr-Jul 95.
MAR 96 28P
PERSONAL AUTHORS: Zum Brunnen, Richard L.

UNCLASSIFIED REPORT

ABSTRACT: (U) The Project Manager for the Corps Surface-to-Air Missile (PM CORPS SAM) is planning to use the U.S. Army Research Laboratory's (ARL) Army Unit Resiliency Analysis (AURA) model to assess the weapon system's performance. Part of the effort included a review of modifications made to AURA by PM CORPS SAM's contractor MEVAThC. This report is a result of the review of MEVAThC's "All Clear" algorithm used in determining when personnel can remove mission-oriented protective posture (MOPP) gear.

DESCRIPTORS: (U) *CHEMICAL WARFARE, *SURFACE TO AIR MISSILES, COMPUTER PROGRAM DOCUMENTATION, MATHEMATICAL MODELS, ALGORITHMS, COMPUTERIZED SIMULATION, NUCLEAR WEAPONS, ARMY RESEARCH, ANTIMISSILE DEFENSE SYSTEMS, SURVIVABILITY, VULNERABILITY, WEAPON SYSTEM EFFECTIVENESS, MISSIONS, THREAT EVALUATION, PROTECTIVE EQUIPMENT NUCLEAR CLOUDS, MASS DESTRUCTION WEAPONS, LETHALITY, INTERCEPTORS, SUBROUTINES, RESILIENCE.

IDENTIFIERS: (U) AURA (ARMY UNIT RESILIENCY ANALYSIS), MOPP (MISSION ORIENTED PROTECTIVE POSTURE).

AD-A303 806

MASSACHUSETTS UNIV
AMHERST, MA

(U) Engineering of Proteins and Devices for Biosensor Applications.

SEP 95 18P
PERSONAL AUTHORS: Tirrell, David A.

UNCLASSIFIED REPORT

ABSTRACT: (U) The technical objective of this project is the development of new sensors for the detection of organophosphate pesticides and chemical warfare agents. A critical step in the fabrication of such sensors is the coupling of an appropriate enzyme to a sensing element, e.g., an electrode or an optical fiber. We have proposed the re-engineering of the phosphotriesterase from pseudononas diminuta or flavobacterium, such that it will assemble spontaneously on glass sensing elements without loss of activity. This enzyme has previously been isolated, cloned, and expressed in E. coli, and has been shown to hydrolyze the commonly used organophosphorus insecticides dursban, parathion, diazinon and cyanophos as well as the nerve agents sarin and soman. The enzyme has also been shown to retain activity when adsorbed on trityl agarose. Much of this work has been done by Raushel and coworkers at Texas A&M University, in part in collaboration with Durst and Landis at Aberdeen Proving Ground. Important contributions have also been reported by Mulbry and Karns at USDA. Professor Raushel has kindly supplied us a plasmid carrying the opd (organophosphorus degrading) gene in a form suitable for expression of the enzyme in E. coli.

DESCRIPTORS: (U) *PROTEINS, *BIOLOGICAL DETECTION, *ORGANIC PHOSPHORUS COMPOUNDS, *ORGANOPHOSPHATES, *PSEUDOMONAS, DETECTION, DETECTORS, ENZYMES, GLASS, PLASMIDS, ESCHERICHIA COLI, ENGINEERING, CLONES, LOSSES, INSECTICIDES, NERVE AGENTS, CHEMICAL WARFARE AGENTS, GB AGENT, PESTICIDES, PARATHION, DIAZINON.

IDENTIFIERS: (U) *BIOSENSORS, ORGANOPHOSPHATE PESTICIDES, PSEUDOMONAS DIMINUTA, FLABOBACTERIUM.

AD-A302 968

PRINS MAURITS LABORATORIUM TNO RIUSWIJK (NETHERLANDS)

(U) Immunochemical and Mass Spectrometric Detection of Mustard Gas Adducts to DNA and Proteins: Verification and Dosimetry of Exposure to Mustard Gas.

JUN 95 270P
PERSONAL AUTHORS: Benschop Hendrik P.; Van der Schans, Govert P.

UNCLASSIFIED REPORT

ABSTRACT: (U) The use of sur mustard and nerve agents in the Iran-Iraq conflict and of sarin in a recent terrorist attack as well as the threat of chemical warfare in the recent Gulf War have stressed the need of reliable methods to detect the nature and extent of poisoning with chemical warfare agents. In this context we have extended our investigations on immunochemical detection of sur mustard adducts to DNA and proteins. Furthermore mass spectrometric methods have been developed as independent highly sensitive techniques having an almost absolute speceicity. A method was developed for analysis of N7<2-hydroxyethylthioethyl)-guanine (N7-HETE- Gua) in digested DNA based upon HPLC with electrochemical detection which is suitable for calabration of methods for adduct detection. The lower detection limit for exposure of human blood is 0.3 uM sulfur mustard with immnofluorescence microscopy using monoclonal antibodies raised against this adduct and 0.07 uM (1 N7-HETE-Gua/1. 4x10(7) nucleotides) with the less laborious immunoslotbiot assay. Detection of the adduct in human skin by immunofluorescence microscopy was improved resulting in a detection limit of a 15-s exposure to saturated sulfur-mustard vapor (Ct ca. 275 tg.min/m3) 1. e. far below the level that would give blisters. With the immunoslotblot assay an exposure of human skin (ca. 5x5 mm) for only 1 sec is detectable (Ct ca. 18 mg.min/m3).

DESCRIPTORS: (U) *DEOXYRIBONUCLEIC ACIDS, *GASES, *MUSTARD AGENTS, *SULFUR *IN VIVO ANALYSIS, *MASS SPECTROMETRY, *DOSIMETRY METHODOLOGY, WARFARE, GULFS, REMOVAL, DETECTION, DAMAGE, VERIFICATION, EXPOSURE (GENERAL), THREATS, HUMANS, PROTEINS, ATTACK, SENSITIVITY, MICROSCOPY, RELIABILITY, LIMITATIONS, CHEMICAL WARFARE, LOW LEVEL, POISONING, CALIBRATION, MICE, MONOCLONAL ANTIBODIES, TERRORISM, KIN (ANATOMY), NERVE AGENTS, BLOOD, CHEMICAL WARFARE AGENTS, GB AGENT, LEUKOCYTES, BIOPSY, BLOOD CELLS.

AD-A302 828

INDUSTRIAL AND BIOMEDICAL SENSORS CORP
WALTHAM, MA

(U) Nondestructive Reactivation of Chemical Protective Garments.

Dec 95 101P
DESCRIPTIVE NOTE: Final rept Jun 85-Jul 89.
PERSONAL AUTHORS: Chang, Kuo W.; Chang, Sanlu Y.; Klemperer, Elizabeth.

UNCLASSIFIED REPORT

ABSTRACT: (U) In the near future, chemical protective combat uniforms may be worn by Army personnel on a continuous basis. Activated carbon, the operative component, has diminished capacity for absorbing chemical agents after it has been exposed to dirt, sweat, cigarette smoke, engine exhaust, petroleum products and numerous other elements routinely present in the battlefield environment. This report summarizes the development of two nondestructive methods for cleaning and reactivating solid chemical protective garments. Complete reactivation was achieved when the aqueous! i-propanol! iodine displacement method of Manes, which removed all but pure hydrocarbon oil soils from the current overgarment Type III foam or Kynol activated carbon fiber material, was applied in nonaqueous solvent. Subsequently, a nonaqueous solvent method that requires less handling was chosen in designing a truck-mounted system. It features non-agitative flow of methylene chloride and methanol around the chemical-protective garments suspended between ultrasonic transducers. Both methods restore full sorptivity to the Type III foam liner. There is a one-time 10X loss of activated carbon without any loss of sorptivity. The volatile solvents are more easily removed, and can be economically recovered. Overall features of a mobile unit have been sketched.

DESCRIPTORS: (U) *NONDESTRUCTIVE TESTING, *ACTIVATED CARBON, *CHEMICAL AGENTS, *PROTECTIVE CLOTHING, WARFARE, ACTIVATION, EXPOSURE (GENERAL), ARMY PERSONNEL, BATTLEFIELDS, CHEMICALS, MATERIALS, DISPLACEMENT, CARBON FIBERS, PURITY, SOILS, ULTRASONICS, METHANOLS, MOBILE HYDROCARBONS, WEAR, IODINE, CHLORIDES, DIRT, ENGINES, SOLVENTS, VOLATILITY, TRANSDUCERS, MOUNTS, TRUCKS, METHYLENES, OILS, ORGANIC SOLVENTS, PETROLEUM PRODUCTS, UNIFORMS, TOBACCO SMOKING.

✦AD-A302 657

INSTITUTE FOR DEFENSE ANALYSES
ALEXANDRIA, VA

(U) Potential Values of a Simple BW Protective Mask.

SEP 95 27P
PERSONAL AUTHORS: Lowe, Karl; Pearson, Graham; Utgoff, Victor.

UNCLASSIFIED REPORT

ABSTRACT: (U) Proliferation of nuclear, biological, and chemical (NBC) weapons is a growing concern. Unless the spread of these weapons can somehow be halted, major changes will be required in allied defense strategy and capabilities. The risks and costs of defending vital interests will arise substantially. Correspondingly, the US, the UK, and their allies will find defense of their important interests more difficult and painful, and other states will become far less willing to support such defense efforts. Recognizing this, the allies are aggressively searching for more effective political means to halt NBC proliferation, and, to the extent it cannot be halted, for military and technical means to counter it. Clearly these pursuits complement each other. Political measures can complicate, slow, and deter proliferation and strengthen the basis for international reaction when evidence of prohibited programs appears. Thus, they should reduce the number and scope of the NBC weapons programs to be countered, buy time to deploy countermeasures, and win domestic and international political support for difficult counterproliferation actions. At the same time, better means of countering NBC weapons should decrease demand for them by reducing their political and military utilities.

DESCRIPTORS: (U) *NUCLEAR WARFARE, *BIOLOGICAL AGENTS, *DEFENSE SYSTEMS *CHEMICAL AGENTS, *PROTECTIVE MASKS, WEAPONS, POLITICAL SCIENCE, STRATEGY, COSTS, RESPONSE, INTERNATIONAL, VALUE, DOMESTIC, COUNTERMEASURES.

IDENTIFIERS: (U) NBC (NUCLEAR BIOLOGICAL AND CHEMICAL).

✦ Included in *The DTIC Review*, December 1996

AD-A302 514

ARMY MEDICAL RESEARCH INST OF
CHEMICAL DEFENSE
ABERDEEN PROVING GROUND, MD

(U) Comparison of Acetylcholinesterase, Pyridostigmine, and Hl-6 as Antidotes against Organophosphorus Compounds.

1995 9P
PERSONAL AUTHORS: Maxwell, Donald M; Brecht, Karen M; Saxena, Ashima; Taylor, Palmer; Doctor, Bhupendra P.

UNCLASSIFIED REPORT

AVAILABILITY: Pub in Enzymes of the Cholinesterase Family, p353-360, 1995. Available only to DTIC users. No copies furnished by NTIS.

ABSTRACT: (U) Conventional medical treatment against the toxicity of organophosphorus (OP) compounds consists of a regimen of anticholinergic drugs to counteract the accumulation of acetylcholine and oximes to reactivate OP-inhibited acetylcholinesterase (AChE) (Taylor, 1985). Reactivation of OP-inhibited AChE by oximes can generate enough active AChE in the peripheral nervous system, especially in the diaphragm, to restore normal cholinergic neurotransmission after exposure to many OP compounds. However, some OP compounds, such as soman (pinacolyledhylphosphonofluofidate), inhibit AChE and rapidly age into a form that cannot be reactivated by oximes (De Jong and Wolring, 1984), thereby reducing the ability of oximes to provide protection (Maxwell and Brecht, 1991). The inability of oximes to provide adequate protection against the toxicity of rapidly aging OP compounds stimulated the development of carbamate pretreatment in which carbamylation of AChE effectively protects it against inhibition by OP compounds (Leadbeat-r et al. , 1985). Spontaneous decarbamylation of AChE after the OP compound has been detoxified then generates enough active AChE to allow normal cholinergic neurotransmission. Behavioral side effects from carbamate pretreatment in the absence of exposure to OP compounds have been avoided by the use of cationic pretreatment carbamates, such as pyridostigine, which do not enter the central nervous system.

DESCRIPTORS: (U) *TOXICITY, *ANTIDOTES, *ACETYLCHOLINESTRASE, *CENTRAL NERVOUS SYSTEM, * ORGANIC PHOSPHORUS COMPOUNDS, *ORGANOPHOSPHATES, *PYRIDOSTIMINE BROMIDE, *CHOLINERGIC NERVES, CATIONS, ACTIVATION, COMPARISON, BEHAVIOR, MEDICAL SERVICES, ACCUMULATION, INHIBITION, CHOLINESTERASE INHIBITORS, GD AGENT, PYRIDES, OXIMES, CARAMATES, NEUROMUSCULAR TRANSMISSION, PHERIPHERAL NERVOUS SYSTEM.

AD-A301 364

ARMY MEDICAL RESEARCH INST OF
CHEMICAL DEFENSE
ABERDEEN PROVING GROUND, MD

(U) Efficacy of Tacrine as a Nerve Agent Pretreatment.

1994 22P
PERSONAL AUTHORS: Fricke, Robert F; Koplovitz, Irwin; Scharf, Bruce A; Rockwood, Gary A; Olson, Carl T.

UNCLASSIFIED REPORT

AVAILABILITY: Pub in Drug and Chemical Toxicology, v17 n1 p15-34 1994. Available only to DTIC users. No copies furnished by NTIS.

ABSTRACT: (U) Tacrine (THA) was evaluated in vitro and in vivo as a pretreatment for nerve agent intoxication. In vitro experiments showed that the primary effect of THA was direct inhibition of purified fetal bovine serum acetylcholinesterase (AChE) with a slight effect on slowing the aging rate of nerve agent-inhibited AChE. THA produced significant behavioral effects at doses above 1.7 q/kg, i.m , in the mouse and 3.4 mg(kg, i.m. , in the guinea pig. At the no observable effect level (NOEL) for mice (1.7 mg/kg), THA was effective (P < 0 05) in reducing tabun- and soman, but not sarin induced lethality in mice. Experiments in the guinea pig showed that at the NOEL (3.4 mg/kg, i.m.) THA was not considered a suitable pretreatment for nerve agent intoxication.

DESCRIPTORS: (U) *IN VITRO ANALYSIS, *IN VIVO ANALYSIS, *BOVINES, *NERVE AGENTS, AGING(MATERIALS), PURIFICATION, DOSAGE, BEHAVIOR, MICE, BLOOD SERUM, INHIBITION, GA AGENT, GUINEA PIGS, FETUS, INTOXICATION.

IDENTIFIERS: (U) *TACRINE.

AD-A301 357

ARMY MEDICAL RESEARCH INST OF CHEMICAL DEFENSE
ABERDEEN PROVING GROUND, MD

(U) Efficacy of Injectable Anticholinergic Drugs against Soman-Induced Convulsive/Subconvulsive Activity.

1994 12P
PERSONAL AUTHORS: Anderson, D.R.; Harris, L.W.; Bowersox, S.L.; Lennox, W.J.; Anders, J. C.

UNCLASSIFIED REPORT

AVAILABILITY: Pub in Drug and Chemical Toxicology, v17 n2 p139-148, 1994. Available only to DTIC users. No copies furnished by NTIS.

ABSTRACT: (U) Six FDA approved, injectable compounds benztropine (BZ) biperiden (BIP); dicyclomine (DCL), hyossyamine (HYO); orphenadrine (ORP); scopolamine (SCP) were each compared to diazepam (DZ, the standard) in male guinea pigs against ongoing somane induced convulsive or sub-CV (CV/subCV) activity. Three trained graders concurrently assigned CV/sub-CV scores to each animal based on signs of intoxication at various times post-soman. Animals received (1m) pyridostigmine (28 ug/kg) 30 min before soman (56 mg/ kg) 2 x LD50, atropine (2 mg/kg) admixed with 2-PAM (25 mg/kg) at one min after soman, and the candidate drug preparation at 5.67 min post soman, a time when CV activity was assured BIP and SCP were effective over dosage ranges between 10 and 0.3, and 1.0 and 0.13 mg/ kg, respectively, while the other preparations were less effective at their respective maximum dosages. At the most effective dosages of SCP (1.O mg/kg) and BIP (10 mg/kg), the CV/sub-CV scores were significantly lower ($p<0.05$) than those of DZ. Only 33x90 survival was observed at each of two doses of ORP and one dose of HYO; therefore, no further testing was done with these compounds. Using freshly prepared solutions, DCL (up to 40 mg/kg) and BZT (up to 96 mg/kg) were tested with mixed results; DCL lowered lethality while BZT increased lethality. CV/sub-CV scores for the most effective dose of DCL and BZT were, however, lower than those of DZ. SCP is an antimuscarinic drug devoid of antinicotinic activity, while BIP possesses antimuscarinic, antinicotinic, antispasmodic and anti-N-methyl-D-aspartate activity. Recent evidence suggests that, in late stages of intoxication by nerve agents, noncholinergic, excitatory amino acid receptors may become involved and necessitate the use of a multi-action drug like BIP.

DESCRIPTORS: (U) *DRUGS, *NERVE AGENTS, *GD AGENT, *INTOXICATION, INJECTION, PREPARATION, LETHALITY, MALES, AMINO ACIDS, PYRADINES, CHOLONERGIC NERVES, ATROPINE, EARTH HANDLING EQUIPMENT, DIAZEPAM, GUINEA PIGS, MUSCARINE, CONVULSIVE DISORDERS, SCOPOLAMINE.

AD-A300 402

MEDICAL BIOLOGICAL LAB RVO-TNO RIJSWIJK (NETHERLANDS)

(U) Neurotoxicity of Cholinesterase Inhibitors Mechanism, Prophylaxis, and Therapy (Organophosphates) Subtitle: Effects of TCP and Additional Drug Treatment on Soman-Induced Convulsions and Brain Damage. A Study on Symptomatology, EEG and Pathology in Rat.

Dec 94 138P
DESCRIPTIVE NOTE: Final rept.1 Dec 91-30 Nov 94.
PERSONAL AUTHORS: De Groot, Didima M.; Bierman, E.P.; Van Huygevoort, A.H.; Melchers, B.P.; Bruijnzeel, P. L.

UNCLASSIFIED REPORT

ABSTRACT: (U) The effects of the non-competitive N-methyl-D-aspartate (NMDA) receptor antagonist N-1-(2MIENYL) CYCLOHEXYLpiperidine (TCP) treatment on soman induced convulsions, EEG seizures and brain damage were studied in rats, some of which were with drugs to protect against lethality. For comparison, pilot studies with another NMDA receptor antagonist MK801 were carried out. The results showed that, to establish a neuroprotective effect of TCP, it seems essential to interfere at earlier stages in the sequence of events leading to convulsions and brain damage. Interference at the level of the NMDA receptor only, does not sufficiently prevent neuropathology after soman. We also demonstrated that various brain regions are involved differently in the sequence of events leading to seizures and brain damage after soman. In addition, the results emphasize that choices for combinations of therapeutics and injection time schedules effective in one species cannot simply be extrapolated to others. In our hands TCP was only effective in modifying the symptomatology at a later stage of the soman intoxication and in reducing the neuropathology after pretreatment with scopolamine and diazepam. Then, particularly in the piriform cortex and amygdala, areas crucial in the generation of seizures, brain damage was reduced. Effective protection against the pathophysiological effects of organophosphates must be sought in a combination of drugs, interfering differently in the sequence of events leading to convulsions and brain damage. TCP (-analogues) appear as promising drugs for additional treatment of soman intoxicated individuals. For reasons discussed, the guinea pig is 1ikely to be a better animal model to study the mechanisms of soman intoxication.

DESCRIPTORS: (U) *TOXICITY, *NERVOUS SYSTEM, *DRUGS *CHOLINESTERASE INHIBITORS, *ORGANOPHOSPHATES *CHEMOTHERAPY, *ELECTROENCEPHALOGRAPHY, *BRAIN DAMAGE *SCOPOLAMINE, BRAIN, MODELS, SIGNS AND SYMPTOMS, THERAPY ANIMALS, PHYSIOLOGY, LETHALITY, PATHOLOGY, PILOT STUDIES, GD AGENT, PREVENTIVE MEDICINE, HANDS, DIAZEPAM.

AD-A300 125

ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE (PROVISIONAL) ABERDEEN PROVING GROUND, MD

(U) Glossary of Terms for Chemical Agents and Chemical Defense Equipment

DEC 94 82P
PERSONAL AUTHORS: Kistner, Stephen.

UNCLASSIFIED REPORT

ABSTRACT: (U) U.S. Center for Health Promotion and Preventive Medicine developed the Glossary to assist in standardizing terminology and providing insight into the technical subtleties associated with discussions of chemical agents and chemical defense equipment. This technical guide will assist in solving problems on the integrated battlefield.

DESCRIPTORS: (U) *VOCABULARY, *CHEMICAL ORDNANCE, *CHEMICAL WARFARE AGENTS, *DICTIONARIES, INTEGRATED SYSTEMS, DEFENSE SYSTEMS, BATTLEFIELDS, HEALTH, PROBLEM SOLVING, CHEMICAL AGENTS, STANDARDIZATION, PREVENTIVE MEDICINE.

IDENTIFIERS: (U) TERMINOLOGY.

AD-A297 350

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD RALSTON (ALBERTA)

(U) Development of Enzyme-Linked Immunosorbent Assay (ELISAS) to Anthrax for the Persian Gulf.

Jul 95 38P
PERSONAL AUTHORS: Nagata, Les P.; Schmalty, Fay L.; Balogh, Carol; Bhatti, A.R.; Cherwonogrodzky, John W.

UNCLASSIFIED REPORT

ABSTRACT: (U) This report details the research that went into the bacterial component of the enzyme-based immunoassays developed for the Mobile Agent Identification Unit (MAGIDU), and were deployed during Operation Friction in the Persian Gulf in 1991. A rapid whole cell enzyme-linked immunosorbent assay (ELISA) was quickly developed for the identification of selected bacterial agents. The early research concentrated on the identification of Bacillus anthracis whole cells, and the resulting assays were fielded in the Persian Gulf. Anthrax could be reliably detected. In 5.5 hrs at concentrations as low as 4.6 x i05 cells/ niL (2 Lg/rnL). An assay with shortened incubation times was later developed (assay run time of 3.0 - 3.5 hr) with a sensitivity of detection of 1.2 x 108 cells/mL (5 g/rnL). Technical details in the development of these assays are discussed, as well as recommendations for future work.

DESCRIPTORS: (U) *ENZYMES, *IMMUNOASSAY, *BACILLUS ANTHRACIS, BIOLOGICAL AGENTS, DETECTION, PERSIAN GULF, BACTERIA, CELLS, REDUCTION, IDENTIFICATION, MOBILE, OPERATION, INCUBATION, ANTHRAX, FRICTION.

IDENTIFIERS: (U) ELISA (ENZYME LINKED IMMUNOSORBENT ASSAY).

AD-A297 154

BRIGHAM YOUNG UNIV
PROVO, UT

(U) The Use of the Bacillus Species to Express the Bacillus Anthracis Toxin Genes for Vaccine Studies.

JUN 95 39P
PERSONAL AUTHORS: Robinson, Donald L.; Woolley, Earl.

UNCLASSIFIED REPORT

ABSTRACT: (U) We have constructed vectors for the high-level expression of the anthrax toxin genes. We have cloned the T7 RNA polymerase gene downstream from the IPTG-inducible prometer from pSI-1. IPTG induces expression of the T7 RNA polymerase when the lacI repressor is inactivated. This integration plasmid has been inserted into the genom of Bacillus anthracis. Shuttle vectors for the expression of the individual anthrax toxin genes (derived from pDR181) consist of the replication components from pUBi110, a kanamycin resistance gene and the multicloning sequence from pET21a, which contains the T7 RNA polymerase promoter and terminator. The individual toxin genes have been inserted into this plasmid. Six recombinant IZAP clones which contain B. Anthracis DNA sequences homologous to the spoOH gene of B subtilts have been isolated. The spoOH gene in the Bacillus species is required for sporulation. This gene will be used to produce an asporogenic B anthracis.

DESCRIPTORS: (U) *TOXINS AND ANTITOXINS, *VACCINES, *BACILLUS ANTHRACIS, RESISTANCE, BACILLUS, DEOXYRIBONUCLEIC ACIDS, SEQUENCES, GENES, CLONES, GENETIC ENGINEERING, ANTHRAX, RIBONUCLEIC ACIDS, BACTERIAL TOXINS, ANTIBIOTICS.

AD-A295 881

ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE
NATICK, MA

(U) A Physiological Evaluation of Advanced Battledress Overgarment Prototypes (ABDO).

JUN 95 49P
PERSONAL AUTHORS: Santee, W.R.; Matthew, W.Y.; Endrusick, T. L.

UNCLASSIFIED REPORT

ABSTRACT: (U) The purpose of the study was to evaluate the heat strain experienced by volunteer test subjects exposed to heat stress while exercising in 5 different chemical protective (OP) overgarments. The study was funded by the U.S. Army Natick Research Development and Engineering Center (Natick). The application of the study was to provide the sponsoring agency sufficient data to compare 4 prototype garments to the existing Battledress Overgarment (BDO) and to select prototypes for further development and possible procurement. This report will describe step-by-step the methods and results of a biophysical evaluation of prototype Advanced Battledress Overgarments (ABDOs).

DESCRIPTORS: (U) *PROTECTIVE CLOTHING, *CHEMICAL WARFARE AGENTS, TEST AND EVALUATION, VOLUNTEERS, PROTOTYPES, PHYSIOLOGICAL EFFECTS, PROCUREMENT, HEAT STRESS (PHYSIOLOGY), BIOPHYSICS.

IDENTIFIERS: (U) DESERT SHIELD OPERATION, DESERT STORM OPERATION.

AD-A295 824

BATTELLE MEMORIAL INST
COLUMBUS, OH

(U) Multiple Animal Studies for Medical Chemical Defense Program in Soldier/Patient Decontamination and Drug Development. Task 85-18: Conduct of Pralidoxime Chloride, Atropine in Citrate Buffer and Pyridostigmine Bromid Pharmacokinetic Studies, and Comparative Evaluation of the Efficacy of Pyridostigmine Plus Atropine and Pralidoxime Versus Atropine and Pralidoxime Alone against Acute Soman Poisoning in Male Rhesus Monkeys.

OCT 94 23P
PERSONAL AUTHORS: Olson, C.

UNCLASSIFIED REPORT

ABSTRACT: (U) Multiple Animal Studies for Medical Chemical Defense Program in Soldier/Patient Decontamination and Drug Development. Task 85-18: Conduct of Pralidoxime Chloride, Atropine in Citrate Buffer and Pyridostigmine Bromid Pharmacokinetic Studies, and Comparative Evaluation of the Efficacy of Pyridostigmine Plus Atropine and Pralidoxime Versus Atropine and Pralidoxime Alone Against Acute Soman Poisoning in Male Rhesus Monkeys.

DESCRIPTORS: (U) *DECONTAMINATION, *DRUGS, *MEDICAL SERVICES, *PYRIDOSTIGMINE BROMIDE, *ATROPINE, BUFFERS, DEFENSE SYSTEMS, ARMY PERSONNEL, CHEMICAL WARFARE, POISONING, ANIMALS, MALES, PATIENTS, PHARMACOKINETICS, CITRATES, GD AGENT, PREVENTIVE MEDICINE, RHESUS MONKEYS.

IDENTIFIERS: (U)*PRALIDOXIME CHLORIDE.

AD-A294 868

RUSSIAN ACADEMY OF SCIENCES NOVOSIBIRSK
INST OF CHEMICAL KINETICS AND COMBUSTION

(U) Chemistry of Destroying Chemical Warfare Agents in Flame.

DESCRIPTIVE NOTE: Technical project rept.
Apr 94 - May 95.
PERSONAL AUTHORS: Korobeinichev, Oleg P.; Chernov, Anatoliy A.; Shvartsberg, Vladimir M.; Il'in, Sergei B.; Mokrushin, Vladimir V.

UNCLASSIFIED REPORT

ABSTRACT: (U) The goal of the research is to increase our understanding of flame chemistry of organophosphorus compounds (OPC). This class of chemicals includes chemical warfare agents (CWAs) such as the nerve agents GB, GD and VX, stockpiles of which in the United States and Former Soviet Union are scheduled for destruction by incineration or other technologies. Although high CWA destruction efficiency has been demonstrated in incinerator tests in the U.S. it is necessary to improve technology for achieving higher efficiency and lower level of pollutants. The knowledge of detailed destruction chemistry of the CWA and simulants can be obtained by studying the structure of flames, doped with simulants and CWA and by the development of the combustion model which will include the chemical mechanism of destroying CWA in flame. Alkyl phosphates are typical organophosphorus compounds, that are simulants of sarin.

DESCRIPTORS: (U) *DESTRUCTION, *CHEMISTRY, *FLAMES, *CHEMICAL WARFARE AGENTS, *ORGANIC PHOSPHORUS COMPOUNDS, TEST AND EVALUATION, USSR, UNITED STATES, MODELS, CHEMICALS, EFFICIENCY, COMBUSTION, LOW LEVEL, POLLUTANTS, DOPING, INCINERATORS, PHOSPHONATES, NERVE AGENTS, STOCKPILES, GB AGENT, GD AGENT, CHEMICAL AGENT SIMULANTS, ALKYL RADICALS, VX AGENT, PHOSPHATES.

IDENTIFIERS: (U) CWA (CHEMICAL WARFARE AGENT).

AD-A294 768

ARMY BIOMEDICAL RESEARCH AND DEVELOPMENT LAB
FORT DETRICK, MD

(U) Reverse Osmosis Removal of Organic Compounds II. Opportunity Poisons and Nerve Agent Hydrolysates.

MAR 95 42P
PERSONAL AUTHORS: Burrows, W.D.; Sinero, Arcadio P.; Schmidt, Mark 0.

UNCLASSIFIED REPORT

ABSTRACT: (U) Reverse osmosis (RO) rejection of acetic acid, fluoro-, chloro- and bromoacetic acids and hydrazine was investigated in a pilot scale (3 gpm) test unit; RO rejection of methylphosphonic acid and ethyl isopropyl and pinacolyl methylphosphonic acids (nerve agent hydrolysates) was investigated in a bench scale (8 L/hr) test unit. Rejection of acetic acid derivatives was found to be pH and pKa dependent; molecular weight was not a factor for total acids, but rejection was inversely related to molecular weight for free (undissociated) acids. Rejection of all methylphosphonates exceeded 99 percent at pH 3 to 10 and was not pH dependent. Rejection of hydrazine sulfate (a surrogate for UDMH) was no better than 90 percent at pH 7.

DESCRIPTORS: (U) *DECONTAMINATION, *REVERSE OSMOSIS, *POISONS, *NERVE AGENTS, *CHEMICAL WARFARE AGENTS REMOVAL, HYDRAZINES, MOLECULAR WEIGHT, ISOMERS, SULFATES, REJECTION, ACIDS, PHOSPHONIC ACIDS, PROPANOLS, ACETIC ACID.

AD-A294 693

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD RALSTON (ALBERTA)

(U) An Assessment of the Effects of Concentration Fluctuations on the Penetration of Toxic Vapors Through a Carbon Bed.

MAY 95 32P
PERSONAL AUTHORS: Yee, Eugene C.

UNCLASSIFIED REPORT

ABSTRACT: (U) A simple mathematical model for the penetration of a vapor through an adsorbent carbon bed has been used to investigate the effects of naturally induced concentration fluctuations on the breakthrough time and the degree of penetration through the bed. The model shows that the breakthrough profile through a carbon bed at time t(sub r) depends on the instantaneous inlet concentration at the retarded time t(sub r) and on the dosage level to which the bed is exposed up to t(sub r). The retarded time t(sub r) is determined by the residence time of the air stream in the carbon bed. Computer simulations, using a steady and a time varying (fluctuating) inlet concentration with the same dosage over a fixed exposure time, show that the time varying exposure can result in a breakthrough time that is reduced by 50% and a breakthrough (exit) concentration that is increased by 25-fold compared with that from the steady exposure in consequence, the effect of concentration fluctuations on vapor penetration through a carbon bed can be significant, and its neglect can lead to an underestimation of the penetration (at least for the simple local rate of removal mechanism assumed for the present model). It should be emphasized that the model used here for the investigation of the vapor penetration through a carbon bed is highly idealized in particular. It was assumed that the vapor in the bed was adsorbed irreversibly (i.e., no desorption) with the local rate of removal taken to be first-order with respect to the vapor concentration and the concentration of unoccupied adsorption sites.

DESCRIPTORS: (U) *VAPORS, *TOXICITY, *CARBON, *PENETRATION, *BEDS (PROCESS ENGINEERING), *CONCENTRATION (CHEMISTRY), *CHEMICAL WARFARE AGENTS, MATHEMATICAL MODELS, COMPUTERIZED SIMULATION, STEADY STATE, CLOUDS, REMOVAL, EXPOSURE (GENERAL), AIR FLOW, RATES, BOUNDARY LAYER, DOSAGE, LEVEL (QUANTITY), PROTECTIVE EQUIPMENT, BIOLOGICAL WARFARE AGENTS, DESORPTION ATMOSPHERES, GREAT BRITAIN, DISPERSIONS, ADSORBENTS CHARCOAL, AIR FILTERS.

IDENTIFIERS: (U) ATMOSPHERIC DISPERSION, CHARCOAL FILTERS, HAZARD ASSESSMENTS, DOWNWIND CLOUDS, FOREIGN REPORTS.

AD-A294 612

MICHIGAN UNIV
ANN ARBOR, MI

(U) Chemical Blistering Cellular and Macromolecular.

OCT 94 81P
PERSONAL AUTHORS: Bernstein, I.A.

UNCLASSIFIED REPORT

ABSTRACT: (U) The mission of this project was to determine the cellular and molecular lesions associated with cutaneous vesication from bis (2-chloroethyl) sulfide (BCES). Cultures of keratinocytes were used to focus attention on the direct interactions between the mustard and its epidermal targets. The technical objectives included confirming that DNA was the primary molecular target of BCES in human epidermal keratinocytes, identifying and quantifying BCES-mediated DNA-adducts in relation to dose, determining why epidermal basal cells are more susceptible to BCES than differentiated cells and investigating the possible role of informational error in DNA. In the cytopathogenic process data generated in the project suggest that (a) DNA is the primary epidermal target of BCES, and the fidelity of DNA repair governs survival of the germinative population, and (b) BCES causes a decrease in the germinative population by cellular differentiation, as indicated by the appearance of mixture keratin protein, as well as necrosis.

DESCRIPTORS: (U) *DEOXYRIBONUCLEIC ACIDS, *CHEMICAL AGENTS, *ALKYLATION, *CHEMICAL INDICATORS, INTERACTIONS, MOLECULES, TARGETS, SURVIVAL (GENERAL) REPAIR, ERRORS, MACROMOLECULES, PATHOLOGY, CELLS (BIOLOGY), POROUS MATERIALS, LESIONS, NECROSIS, VESICANTS, SKIN DISEASES, TISSUE CULTURE.

AD-A294 185

ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE
NATICK, MA

(U) The Impact of the NBC Clothing Ensemble on Respiratory Function and Capacities During Rest and Exercise.

MAY 95 74P
PERSONAL AUTHORS: Muza, Stephen R.; Banderet, Lou; Forte, Vincent A.

UNCLASSIFIED REPORT

ABSTRACT: (U) This study examined the effects of wearing a modified MOPP (mMOPP) overgarment (Protective Clothing, PC), configured with body armor (BA), Load Bearing Equipment (LBE), and M40 CB mask on the pattern and mechanics of breathing and cognitive functioning in 15 male soldiers at rest and during sustained submaximal exercise (approx 600 W). The M40 CB mask reduced breathing capacity 20X, and the PC+BA+LBE components of the mMOPP reduced it 5%. Total respiratory system compliance decreased by 18% in the mMOPP. Thus, wearing the PC+BA+LBE increased the "stiffness" of the soldier's respiratory system. During exercise, the mMOPP decreased tidal volume and increased respiratory rate, a compensation for the decreased respiratory system compliance. Although the M40 CB mask imposes a significant impairment to breathing, the PC with BA and LBE presents a unique external constraint on breathing, which may be more aversive than that imposed by the CB mask. These impairments may be reduced by wearing BA and LBE that are properly fitted over the PC and incorporating, in future designs, enhancements that allow for outward expansion of the PC, BA or LBE with inhalation.

DESCRIPTORS: (U) *NUCLEAR WARFARE, *BIOLOGICAL WARFARE, *CHEMICAL WARFARE, *RESPIRATORY SYSTEM, *PROTECTIVE CLOTHING, *EXERCISE (PHYSIOLOGY), VOLUME, ARMY PERSONNEL, LOADS (FORCES), COGNITION, STIFFNESS, RATES, MECHANICS, PATTERNS, SUPPORTS, EXPANSION, RESPIRATION, CLOTHING, MASKS, INHALATION, TIDES, BODY ARMOR.

IDENTIFIERS: (U) NBC (NUCLEAR BIOLOGICAL AND CHEMICAL).

AD-A292 315

GEO-CENTERS INC.
FORT WASHINGTON, MD

(U) Evaluation of the Efficiency of Microclimate Cooling in a Hot Weather CBR Environment.

NOV 94 95P
PERSONAL AUTHORS: Wittmers, L.; Hoffman, R.; Israel, D.; Ingersoll, B.; Canine, K.

UNCLASSIFIED REPORT

SUPPLEMENTARY NOTE: Prepared in collaboration with Minnesota Univ, Duluth.

ABSTRACT: (U) The threat of chemical warfare associated with the war in the Persian Gulf revealed that insufficient information available regarding military personnel who can be exposed to both a hot environment and chemical/biological attack. The chemical, biological, radiological (CBR) protective ensembles worn under threat of chemical/ biological attack prevent noxious agents from reaching the skin; however heat metabolically generated or gained from the environment is prevented from dissipating. Thus in this scenario, microclimate cooling may be essential to prevent heat injury. This study was designed to determine the efficiency of a microclimate cooling system (MCS) in preventing heat strain in six unacclimated males who performed moderate exercise (walking at 3 mph, 2X (grade) in a hot environment (100f) , while encapsulated in a chemical protective overgarment with either no cooling (NC), intermediate cooling (IC) (coolant flow rate = 225 ml/min), or maximal cooling (MC) (coolant flow rate = 450 ml/min). Heart rate (HR), core temperature (Tr%) and stay time were measured as indices of heat strain. There was 110 difference in HR or Tr% at 50 min and 90 min between the IC and MC conditions, and all participants reached the maximal time limit (120 min) in both conditions. HR and T were lower in the IC and MC conditions than the NC condition at min 90 and stay time was longer in IC and MC than NC. The USC of this MCS reduced cardiovascular stress, as estimated by increases in 1-HR and reduced thermal stress, as estimated by increases in Tr; however, the higher coolant flow rate conferred no thermoregulatory advantage over the lower flow rate.

DESCRIPTORS: (U) *BIOLOGICAL WARFARE, *CHEMICAL WARFARE, *PROTECTIVE CLOTHING, *MICROCLIMATOLOGY, STRESSES, MILITARY PERSONNEL, WARFARE, CORES, THREATS, TEMPERATURE, PERSIAN GULF, EFFICIENCY, COOLING, ESTIMATES, FLOW RATE, TOXIC AGENTS, COOLING AND VENTILATING EQUIPMENT, WOUNDS AND INJURIES COOLANTS, HEART RATE, CARDIOVASCULAR SYSTEM, HEAT STRESS .

AD-A291 280

ARMY MEDICAL RESEARCH INST OF INFECTIOUS DISEASES
FORT DETRICK, MD

(U) Preliminary Trials of Oral Immunization of Wildlife Against Anthrax.

MAY 94 18P
PERSONAL AUTHORS: Rengel, O.; Boehnel, H.

UNCLASSIFIED REPORT

SUPPLEMENTARY NOTE: Trans of Berliner und Munchener Tierarztlich Wochenschrift (Germany) v107 n5 p145-149 May 94.

ABSTRACT: (U) In pilot trials relating to the vaccination of wild animals in African game reserves, guinea pigs were vaccinated against anthrax. The vaccine was prepared in suspension using the Goettingen IBT Bioreactor method. Guinea pigs immunized orally or subcutaneously survived infection by 1000 spores from a field strain isolated from an elephant in the Luangwa Valley Animal Reserve in Zambia. The animals immunized orally or subcutaneously and infected with 2500 spores died. A technique was developed using gas chrozatography to identify B anthracis organisms excreted in the feces. Anthrax as a zoonosis has lost much of its terror in Europe, although there continue to be sporadic reports of human infections in which the pathogen was brought in from a tropical country.

DESCRIPTORS: (U) *ANTHRAX, *VACCINES, *ZOONOSES EUROPE HUMANS, BIOCHEMISTRY, REPORTS, DISEASES, CHEMICAL, REACTORS, SOILS, ANIMALS, TROPICAL REGIONS, INFECTIOUS DISEASES, WILDLIFE, IMMUNIZATION, FECES, GAS CHROMATOGRAPHY, ORAL INTAKE, GUINEA PIGS.

AD-A290 213

ARMY RESEARCH LAB
ABERDEEN PROVING GROUND, MD

(U) NBC Contamination Survivability (NBCCS) of AVENGER.

NOV 94 28P
PERSONAL AUTHORS: Majeski, John D.

UNCLASSIFIED REPORT

ABSTRACT: (U) The Survivability-Lethality Analysis Directorate/Chemical-Biological and Nuclear Effects Division of the U.S. Army Research Laboratory has been tasked by the Project Manager AVENGER office to perform a nuclear-biological-chemical contamination survivability (NBCCS) analysis of the AVENGER system with recommendations of a suitable decontamination plan and cost-effective alternatives, as applicable. This progress report for FY 94 efforts is a compilation of related data/reviews, methodology, schedule for this study, and emerging issues.

DESCRIPTORS: (U) *COLLECTIVE PROTECTION, *AIR DEFENSE SYSTEMS, FIBERGLASS, SURVIVABILITY, DECONTAMINATION COMBAT READINESS, CHEMICAL WARFARE AGENTS, RADIATION HARDENING, GUN TARGETS, UTILITY VEHICLES.

IDENTIFIERS: (U) AVENGER AIR DEFENSE SYSTEM, STINGER MISSILES, HMMWV VEHICLES.

AD-A289 286

EDGEWOOD RESEARCH DEVELOPMENT AND ENGINEERING CENTER
ABERDEEN PROVING GROUND, MD

(U) Treaty Verification Sample Analysis Program Analytical Results: UNSCOM 65 Samples.

JUL 94 330P
PERSONAL AUTHORS: Szafraniec, Linda L; Beaudry, William T.; Bossle, Paul C.; Durst, H.D.; Ellzy, Michael W.

UNCLASSIFIED REPORT

SUPPLEMENTARY NOTE: Prepared in collaboration with EAI Corp., Abingdon, MD and GEO-Centers, Inc., Newton Centre, MA.

ABSTRACT: (U) Nineteen samples from the United Nations Special Commision 65 on Iraq (UNSCOM 65) were analyzed for chemical warfare (CW) related compounds using a variety of highly sophisticated spectroscopic and chromatographic techniques. The samples consisted of six water, six soil, two vegetation, one cloth, one wood, and two mortar shell crosscut sections. No sulfur or nitrogen mustards, Lewsite, or any of their degradation products were detected. No nerve agents were observed, and no tin was detected precluding the presence of stannic chloride, a component of NC, a World War I choking agent. Diethyl phosphoric acid was unambiguously identified in three water samples, and ethyl phosphoric acid was tentatively identified, at very low levels, in one water sample. These phosphoric acids are degradation products of Amiton, many commercially available pesticides, as well as Tabun and impurities in munitions-grade Tabun. No definitive conclusions concerning the source of these two chemicals could be drawn from the analytical results.

DESCRIPTORS: (U) *IRAQ, *DEBRIS *BIOLOGICAL CONTAMINATION, *CHEMICAL WARFARE, *TREATIES, *PUBLIC HEALTH, *CHROMATOGRAPHIC ANALYSIS, NUCLEAR MAGNETIC RESONANCE, INFRARED SPECTROSCOPY, ARMY RESEARCH, DEGRADATION, VERIFICATION, MASS SPECTROSCOPY, LIQUID CHROMATOGRAPHY, QUALITY CONTROL, CHLORIDES, IONIZATION, SULFUR, STORAGE TANKS, SITE INVESTIGATIONS, ENVIRONMENTAL PROTECTION, TIN COMPOUNDS, SOIL CLASSIFICATION NERVE AGENTS, GAS CHROMATOGRAPHY, WOOD, ETHYL RADICALS, GA AGENT, PESTICIDES, NITROGEN MUSTARDS, PHOSPHORIC ACIDS.

IDENTIFIERS: (U) TREATY VERIFICATION, ATOMIC ABSORPTION SPECTROSCOPY, ATOMIC ABSORPTION.

AD-A285 242

EDGEWOOO RESEARCH DEVELOPMENT AND ENGINEERING CENTER
ABERDEEN PROVING GROUND, MD

(U) Adhesive Study for the M40A1 Chemical-Biological Protective- Mask's Quick Doff Hood.

AUG 94 12P
PERSONAL AUTHORS: Fritch, William.

UNCLASSIFIED REPORT

ABSTRACT: (U) An adhesive study was conducted to investigate methods or process to enhance producibility of the quick doff hood for the M40 mask. The quick doff hood design uses taped seams. Variations of the taped seams (alternative adhesives, different tape widths, and a number of adhesive coatings) were investigated. The sample variations were subjected to adhesion, blocking, cold crack, and hydrostatic resistance testing. Test results are discussed in this report and indicate that some of the variations can be used to enhance producibility of the quick doff hood adhesive, M40 Mask quick doff hood.

DESCRIPTORS: (U) *HOODS, *PROTECTIVE MASKS, *CHEMICAL WARFARE, BIOLOGICAL WARFARE, ADHESION, ADHESIVES, BLOCKING, COATINGS, CRACKS, HYDROSTATICS, NUMBERS RESISTANCE, TAPES, TEST AND EVALUATION, VARIATIONS, WIDTH, COLD WEATHER.

IDENTIFIERS: (U) M40 MASK, QUICK DOFF HOOD.

AD-A283 754

DEFENCE SCIENCE AND TECHNOLOGY ORGANIZATION CANBERRA (AUSTRALIA)

(U) Modulation of Mustard Toxicity by Tacrine.

1994 5P
PERSONAL AUTHORS: Gray, Peter; Lewis Kate; Masta, Andrew; Philips, Don.

UNCLASSIFIED REPORT

AVAILABILITY: Pub in Biochemical Pharmacology, v47 n3p581-583 1994. Available only to DTIC users. No copies furnished by NTIS.

ABSTRACT: (U) Compounds containing the chloroethyl group are potent inhibitors of DNA synthesis and cell growth. Tacrin, a choline carrier inhibitor, was found to protect both HeLa cells and rat thymocytes against the effects of nitrogen mustard. DNA synthesis was restored from 13 to 71% of the control value and cell availability restored from 27 to 57% of the control value by exposure of the cells to an equimolar concentration of tactrine immediately prior to nitrogen mustard. In contrast, tactrine was unable to significantly protect rat thymocytes against the toxic effects of sulphur mustard. These results have implications for the clinical use of nitrogen mustard.

DESCRIPTORS: (U) *NITROGEN MUSTARDS, *THYMOCYTES, *AUSTRALIA, *TOXICITY, CELLS, CHOLINES, INHIBITORS, RATS SYNTHESIS, VIABILITY, REPRINTS, PHARMACOLOGY, SULFIDES, BIOCHEMISTRY, MODULATION, CHLORIDES, ETHYL RADICALS DEOXYRIBONUCLEIC ACIDS, SULFUR, ALKYLATION, NUCLEIC ACIDS, REPRINTS.

IDENTIFIERS: (U) FOREIGN REPORTS, *TACRINE, CHLOROTHYL, DNA.

AD-A281 189

DEFENCE RESEARCH ESTABLISHMENT
SUFFIELD RALSTON (ALBERTA)

(U) Clinical Study of a New Therapy for Nerve Agent Poisoning Ascending Dose Tolerance Study of HI-8 + Atropine.

APR 94 41P
PERSONAL AUTHORS: Clement, J. G.; Madill, H D; Bailey, D; Spence, B.

UNCLASSIFIED REPORT

ABSTRACT: (U) This report details a double-blind placebo controlled, ascending dose tolerance and pharmacokinetic study of HI-6 + atropine sulfate 2 mg. In 24 healthy male volunteers- HI-6 was rapidly absorbed from an IM injection site. Maximum HI-6 plasma concentrations of 1.88, 4.96, 8.31 and 15.0 micrograms/ml were found 30-36 min after administration and maintained above 4 micrograms/mL concentration for 0, 39, 112 and 172.5 min following injection of 82.5, 125, 250 or 500 mg HI-6 + atropine (2 mg), respectively. The calculated half life of HI-6 was 78.2 min following 62.5 mg HI-6 + atropine dose and approximately 64-67 min following 125-500 mg HI-6 + atropine doses. Approximately 50% of the total dose of HI-6 was eliminated unchanged in the urin. There were significant changes ($p < 0.05$) in AST, CPK, creatinine and gamma GT following the 500 mg HI-6 + atropine dose but they were not considered to be clinically significant. Urinalysis hematology and semen analysis over the 24 hr observation period was uneventful. There were no clinically significant changes in heart rate or ECG trace, respiration or blood pressure, visual and mental acuity following HI-6 + atropines. The various doses of HI-6 + atropine were well tolerated by the subjects as no serious clinical complaints were reported. With the rapid absorption and the lack of clinically significant side effects, combined with the superior efficacy against all nerve agents, HI-6 shows great promise as a replacement oxime in the therapy of nerve agent poisoning.

DESCRIPTORS: (U) *NERVE AGENTS, PLACEBOS, *POISONING ABSORPTION, ACUITY, ATROPINE, BLOOD PRESSURE, CHEMISTRY, CREATININE, ELIMINATION, EYE, HALF LIFE, HEART, HEART RATE, HEMATOLOGY.

AD-A280 761

GEO-CENTERS INC
NEWTON CENTRE, MA

(U) Traction Characteristics of Chemical Agent Protective Footwear Soleing Materials.

JAN 94 65P
PERSONAL AUTHORS: Hall, Robert.

UNCLASSIFIED REPORT

ABSTRACT: (U) The Static Coefficient of Friction (SCF) values were determined for several footwear soleing materials on different walkway surfaces, and for different surface conditions, to establish which soleing materials provided the best traction performance for shipboard application. The soleing materials evaluated included a standard Navy safety boot with nitrile rubber sole, a Vibration nitrile commercial sole, the Army's prototype nitrile neoprene multipurpose overboot (MULO) and vinyl overshoe, and three butyl chemical protective footwear covers. The walkway surfaces employed were stainless steel aluminum, and new and worn non-skid coated steel. The SCF values were obtained with the surfaces dry, wet, and contaminated with oil. The ASTM Standard-Test Method for Static Coefficient of Friction of Shoe Sole and Heel Materials as measured by the James Machine, was used to determined the SCF values. The standard and MULO nitriles performed best when all walkway surfaces and conditions were considered. The excellent chemical resistance of the nitriles, and their high SCF values for a variety of surfaces and surface conditions evaluated in this study, makes them good candidate soleing materials for chemical agent protective footwear.

DESCRIPTORS: (U) *BOOTS, *NITRILE RUBBER, *SHOES, *TRACTION, ALUMINUM, CHEMICAL AGENTS, FRICTION, MULTIPURPOSE, NAVY, NEOPRENE, OILS, PROTOTYPES, SAFETY, SHIPBOARD, STAINLESS STEEL, STANDARDS, SURFACE PROPERTIES, TEST METHODS, TEST AND EVALUATION, SKIDDING, WEAR RESISTANCE, WALKING, PROTECTIVE CLOTHING.

AD-A278 764

ROTHE DEVELOPMENT INC
SAN ANTONIO, TX

(U) Development of a Ventilated Off-Gassing Booth for Chemical Agent Exposure Studies.

MAR 94 28P
PERSONAL AUTHORS: Moore, Arnotte E.; Kilian, John P.; Luskus, Leonard U; Slate, Alexander R.

UNCLASSIFIED REPORT

ABSTRACT: (U) Chemical Defense (CD) shelter procedures development and ensemble configuration research uses off gassing booths to determine the amount of chemical agent vapor transported by personnel into shelters and to quantify the exposure of individuals to agent vapors. A ventilated off-gassing booth (VOFGB) was designed, constructed, and compared to the non-ventilated booths in use at Air Force test and evaluation facilities to determine whether the VOFGB would make off-gassing assays more accurate reflections of actual exposure. Ventilated booths study results showed that the VOFGB provided more predictable and reproducible values with need for much shorter testing tiles. The static (non-ventilated) off-gassing booths could provide similar superior results but only certain carefully controlled conditions.

DESCRIPTORS: (U) *CHEMICAL AGENTS, *VENTILATION *EXPOSURE (GENERAL), AIR FORCE, CONFIGURATIONS, FACILITIES, PERSONNEL, REFLECTION, SHELTERS, STATICS, TEST AND EVALUATION, VAPORS, COLLECTIVE PROTECTION, CONTAMINATION, MILITARY FACILITIES.

IDENTIFIERS: (U) *OFF-GASSING BOOTH, ENSEMBLE, VOFGB (VENTILATED OFF-GASSING BOOTH).

AD-A277 814

WALTER REED ARMY INST OF RESEARCH
WASHINGTON DC

(U) Huperzine as a Pretreatment Candidate Drug against the Nerve Agent Toxicity

1994 8P
PERSONAL AUTHORS: Grunwald, Jacob; Raveh, Lily; Doctor, Bhupandra P.; Ashani, Yacov.

UNCLASSIFIED REPORT

AVAILABILITY: Pub in Life Sciences v54 n14 p991-997, 1994. Available to DTIC users only. No copies furnished by NTIS.

ABSTRACT: (U) Huperzine A (HUP) is a naturally-occurring, potent, reversible inhibitor of acetylcholinesterase (AChE) that crosses the blood-brain barrier. To examine its ability to protect against nerve agent poisoning HUP was administered i.p. to mice, and the s.c. LD50 of soman was determined at various time intervals after pretreatment. Results were compared to those obtained for animals treated with physostigmine. A protective ratio of approximately 2 was maintained for at least 6 hr after a single injection of HUP, without the need for any post challenge drug therapy. By contrast, pretreatment with physostigmine increased the LD50 of soman by 1.4- to 1.5 fold for only up to 90 min. The long-lasting antidotal efficacy displayed by HUP correlated with the time course of the blood-AChE inhibition. The results suggest that the protection of animals by HUP from soman poisoning was achieved by temporarily sequestering the active site region of the physiologically important AChE.

DESCRIPTORS: (U) *BLOOD BRAIN BARRIER, *DRUGS, *TOXICITY, ACETYLCHOLINESTERASE, ANIMALS, BRAIN, CONTRAST INHIBITION, INHIBITORS, INJECTION, INTERVALS, MICE, NERVE AGENTS, PHYSOSTIGMINE, POISONING, PROTECTION, RATIOS, REGIONS, REVERSIBLE, SITES, THERAPY, TIME, TIME INTERVALS ORGANOPHOSPHATES, OXIMES, HEALTH, REPRINTS.

IDENTIFIERS: (U) *HUPERZINE, SOMAN, ANTOPINE.

AD-A277 288

ARMSTRONG LAB
BROOKS AFB, TX

(U) Aircrew Eye/Respiratory Protection (AERP): 18-Hour Extended Wear Evaluation of Chemical Protective Equipment.

FEB 94 14P
PERSONAL AUTHORS: Nunneley, Sarah A.; Russell, Roberta L.

UNCLASSIFIED REPORT

ABSTRACT: (U) Sixteen-hour wear tests were conducted for the Aircrew Eye-Respiratory Protection (AERP) and associated clothing and equipment. Two subjects each carried out stimulated tanker/transport and fighter/attack scenarios. No major problems were encountered.

DESCRIPTORS: (U) *PROTECTIVE EQUIPMENT, *EYE SAFETY CHEMICAL AGENTS, FLIGHT CREWS, OPERATIONAL EFFECTIVENESS ACCELERATION, PROTECTIVE CLOTHING, TEST AND EVALUATION, THERMAL STRESSES.

IDENTIFIERS: (U) *RESPIRATORY.

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